Altering the temporal distribution of energy intake with isoenergetically dense foods given as snacks does not affect total daily energy intake in normal-weight men

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The objectives of the present study were to examine the effects of (1) ingesting mandatory snacks *v*. no snacks and (2) the composition of isoenergetically-dense snacks high in protein, fat or carbohydrate, on food intake and energy intake (EI) in eight men with *ad libitum* access to a diet of fixed composition. Subjects were each studied four times in a 9 d protocol per treatment. On days 1–2, subjects were given a medium-fat maintenance diet estimated at 1·6 × resting metabolic rate (RMR). On days 3–9, subjects consumed three mandatory isoenergetic, isoenergetically dense (380 kJ/100 g) snacks at fixed time intervals (11.30, 15.30 and 19.30 hours). Total snack intake comprised 30 % of the subjects' estimated daily energy requirements. The treatments were high protein (HP), high carbohydrate (HC), high fat (HF) and no snack (NS). The order was randomized across subjects in a counterbalanced, Latin-square design. During the remainder of the day, subjects had *ad libitum* (meal size and frequency) access to a covertly manipulated medium-fat diet of fixed composition (fat : carbohydrate : protein, 40 : 47 : 13 by energy), energy density 550 kJ/100 g. All foods eaten were investigator-weighed before ingestion and left-overs were weighed after ingestion. Subjective hunger and satiety feelings were tracked hourly during waking hours using visual analogue scales. *Ad libitum* EI amounted to 13·9 MJ/d on the NS treatment compared with 11·7, 11·7 and 12·2 MJ/d on the HP, HC and HF diets respectively ($F(3,21)$ 5·35; $P = 0·007$, SED 0·66). Total EI values were not significantly different at 14·6, 14·5, 15·0 and 14·2 MJ/d respectively. Snack composition did not differentially affect total daily food intake or EI. Average daily hunger was unaffected by the composition of the snacks. Only at 12.00 hours did subjects feel significantly more hungry during the NS condition, relative to the other dietary treatments ($F(3,18)$ 4·42; $P = 0·017$). Body weight was unaffected by dietary treatment. In conclusion, snacking *per se* led to compensatory adjustments in feeding behaviour in lean men. Snack composition (with energy density controlled) did not affect the amount eaten of a diet of fixed composition. Results may differ in real life where subjects can alter both composition and amount of food they eat and energy density is not controlled.

Snacking: Appetite: Energy intake

In Western countries there has been renewed media, consumer and government concern during the 1990s regarding the influence that levels of dietary fats and/or carbohydrates can exert on human health and well-being (e.g. Department of Health, 1995). Throughout this time, the alarming rise in the proportion of overweight and obese adults in Western society has led to considerable debate regarding the underlying causes of these secular trends. Three major factors are frequently cited as being conducive to weight gain in Western populations: (1) reduced levels of physical activity, which decrease total energy expenditure, (2) the ingestion of a high-fat, energy-dense diet, which appears to be associated with higher levels of body fatness in people eating such diets (Lissner & Heitmann, 1995). Ingestion of high-fat, energy-dense foods appears to lead to poor energy compensation during subsequent eating occasions, relative to ingestion of lower-fat, less energy-dense foods (Cotton *et al*. 1994; Blundell & Macdiarmid, 1997). In the long term, ingestion of higher fat diets can lead to weight gain in free-living subjects (Westerterp-Plantenga *et al*. 1998). (3) It has been noted that snacking and commercially available snack foods are often believed to elevate energy intake (EI)

Abbreviations: EI, energy intake; HC, high carbohydrate; HF, high fat; HP, high protein; NS, no snack; RMR, resting metabolic rate.

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(Drummond *et al*. 1996; Gatenby, 1997; Grogan *et al*. 1997; Nunez *et al*. 1998). However, there is considerably less evidence that meal or snack patterns contribute to the development of obesity. It is important to note at this point that the relationship between a meal and a snack relates to timing and size of ingestive events in meal-feeding animals. In non-human species (and indeed human subjects) who engage in numerous small feeding bouts throughout their diurnal cycle there is little, if any, distinction between a meal and a snack. In meal-feeding animals (i.e. animals conditioned to ingest the majority of their EI in a few large ingestive events in their diurnal cycle, usually at approximately the same time points) a snack can be defined as a small ingestive event, occurring in the inter-meal interval and contributing a relatively small fraction of total daily EI. For the purposes of the present study we use the word 'snack' to describe a small inter-meal ingestive event. To avoid confusion with a common use of the word to describe a certain type of commercially available food, we use the phrase 'commercially available snack foods' to describe those specific foods. Commercially available snack foods tend to differ from the rest of the diet as they are more energy dense, high in fat and carbohydrate and low in protein, and usually contain a large fraction of their edible mass as dry matter. They are by no means the only foods eaten as a small inter-meal ingestive event by many people at large.

There are two alternative hypotheses about how snacking may influence EI and body weight: (1) snacking helps to 'fine tune' meal-time EI to match intake with requirements, or (2) habitual consumption of energy-supplying drinks and snacks between meals is a major factor driving EI up and predisposing people to weight gain (Booth, 1988).

The evidence in relation to meal patterns, appetite, EI and body weight is however, indirect and fragmentary. On aggregate, cross-sectional studies tend to support no relationship or a negative relationship between meal frequency and BMI (Fabry *et al*. 1964; Fabry & Tepperman, 1970; Gibney & Lee, 1989). However, Bellisle *et al*. (1997) convincingly argue that examinations of the relationship between snacking and energy balance in free-living subjects are extensively flawed by mis-reporting, mis-classification of meals and snacks and potentially by reverse causality. Under these conditions it is difficult to draw clear conclusions about the effects of snacking in cross-sectional studies. It is therefore important to conduct controlled laboratory interventions over a number of days in human subjects.

It is well known in the animal literature that a variety of species can learn to adapt to meal feeding, snacking or totally *ad libitum* conditions in order to match EI to requirements (Le Magnen, 1992; Forbes, 1995). This suggests some flexibility in adjusting feeding behaviour to feeding schedules in order to meet energy requirements. There appears to be very little direct empirical evidence in human subjects as to whether ingesting snacks *per se* affects appetite and EI. There is some evidence that people who snack frequently exhibit a greater capacity to compensate for changes in the energy content of specific meals, relative to subjects who derive most of their EI from fewer, larger meals (Westerterp-Plantenga *et al*. 1994). Macronutrients exert clear differential effects on appetite when given in loads of 1·0–1·5 MJ or more (JA Weststrate, unpublished results; available from Unilever Research, Vlaardingen, The Netherlands). At the same level of energy density, protein is more satiating than fat or carbohydrate-rich foods (Johnstone *et al*. 1996; Stubbs *et al*. 1996). If this effect persists when macronutrients are included in the diet using snacks as vehicles, spread across the day, protein-rich snacks may help to limit excess EI. The objectives of the present study were to examine the effects of (1) ingesting mandatory snacks *v*. not ingesting snacks, and (2) the composition of isoenergetically-dense snacks high in protein, fat or carbohydrate, on food intake and EI in men with *ad libitum* access to a diet of fixed composition. Thus, in the present study we aimed to introduce snacks as a means of altering the temporal distribution of EI across the day to ascertain whether subjects compensated during the remainder of the day.

Materials and methods

Subjects

Eight healthy, non-smoking men (mean age 27·3 (SD 6·4) years; weight 76·5 (SD 10·2) kg; height 1·8 (SD 0·05) m), were recruited by advertisement. Volunteers were resident in, but not confined to, the Rowett's Human Nutrition Unit for the duration of the study. They were instructed not to undertake strenuous physical activity during the study. All had a history of weight stability and none was taking any medication during the study. Height was measured to the nearest 5 mm using a stadiometer (Holtain Ltd, Crymych, Dyfed, UK). Subjects were weighed (corrected to nude) each morning of the study, after voiding and before eating, to the nearest 10 g on a digital scale (DIGI DS-410; CMS Weighing Equipment Ltd, London, UK). Resting metabolic rate (RMR) was measured by indirect calorimetry over 30–40 min using a ventilated hood system (Deltatrac II, MBM-200; Datex Instrumentarium Corporation, Helsinki, Finland) on subjects who had fasted overnight. RMR was calculated using the equations of Elia & Livesey (1988). This study was approved by the Joint Grampian Health Board and University of Aberdeen Ethical Committee.

Study design

Subjects were each studied on four occasions individually constituting a 9 d period, with at least 1 week between each dietary treatment. On days 1 and 2 subjects were given a fixed, maintenance diet, estimated at 1·6 × RMR. This diet comprised 40 % fat, 47 % carbohydrate and 13 % protein by energy. During the subsequent 7 d, subjects were given continuous *ad libitum* access to a medium-fat diet (40 : 47 : 13 % energy from fat, carbohydrate and protein respectively and an energy density of 550 kJ/100 g) with every item on the menu a constant measurable composition, presented as a 3 d rotating menu. On all but the no-snack condition subjects were also required to consume three mandatory isoenergetically dense snacks of the same energy content at three fixed-time points; 11.30, 15.30 and 19.30 hours. The mean mandatory energy and nutrient intakes of the snack foods given to the eight men are shown in the Appendix (Table 1), recipes are also given in the Appendix (Table 2). The composition of, and menu for, the *ad libitum* foods are described in the Appendix (Tables 3 and 4). The treatments were: high fat (HF), high carbohydrate (HC), high protein (HP), and no snack (NS). Here ‘high’ denotes 70 % by energy and the remainder split evenly between the other two macronutrients. Snacks supplied 30 % of subjects’ energy requirements (at 1·6 × RMR). They were served as a salad, pâté and a yoghurt-style drink. Each of these snacks was made in three versions corresponding to the HP, HC and HF treatments, which were similar in taste, texture and appearance.

Visual analogue scales were completed every waking hour throughout each study day to assess changes in subjective appetite, hunger and satiety.

The *ad libitum* diets, their formulation and presentation are described in detail in the Appendix (Tables 3 and 4). All foods given *ad libitum* were available in excess; they were weighed before ingestion and left-overs were weighed after ingestion.

Statistical analysis

To satisfy assumptions of normality, a square root transformation was applied to the visual analogue ratings and these were then analysed using ANOVA. The transformed visual analogue ratings were then analysed by calculating a mean rating for each 24 h period and applying ANOVA with diet, run and day as factors and subject, run and day as a blocking factor. Additionally, visual analogue ratings were analysed 30 min before and after each snack period at 11.00 and 12.00 hours, 15.00 and 16.00 hours, and at 19.00 and 20.00 hours. Subjectively rated pleasantness and satisfaction was analysed by ANOVA with diet as a factor and subject as a blocking factor. Changes in body weight from day 3 to day 9 were analysed by ANOVA with diet as factor and subject as blocking factor. For each dietary treatment, Wilcoxon matched-pairs tests were used to test for significant changes in body weight. Daily *ad libitum* and total intakes were analysed by ANOVA, with diet as a factor and subject and run as blocking factors. All analysis was performed using the Genstat 5 statistical program (Rothamstead Experimental Station, Harpenden, Herts., UK).

Results

Food, energy and nutrient intakes

Table 1 gives the average daily *ad libitum* food, energy and nutrient intakes exclusive and inclusive of snacks, for the eight men on each dietary treatment, together with the *F*-ratios, SED and probabilities for the main effects. ANOVA confirmed that adding mandatory snacks into the diet of these men led to compensatory reductions in food intake and EI ($F(3,21)$ 5·35; $P = 0·007$). Total daily EI (inclusive of snacks) were not significantly different across treatments ($F(3,21)$ 0·55; $P = 0·654$). Thus, composition of the isoenergetically dense snacks did not significantly affect food intake.

Because the composition of the *ad libitum* diet was constant, food intake, EI and the intakes of all macronutrients (excluding mandatory snacks) were higher on the NS treatment compared with all other treatments.

When intakes were considered inclusive of all mandatory snacks, EI were similar but the intakes of protein, carbohydrate and fat were significantly higher on the HP, HC and HF snack treatments respectively, relative to all other treatments.

In order to assess the impact of the snacking manipulation on patterns of food intake, food and energy intakes were broken down into meals (breakfast, lunch and supper), liquids, salad garnish and snacks. Although not statistically significant, subjects increased EI in all food categories (lunch, supper and snacks) except for breakfast on the NS treatment compared with other treatments. Subjects also consumed significantly more liquid (orange squash and milk shake) on the NS and HP treatments compared with the HC and HF treatments, giving average EI from beverages of 0·7, 0·7, 0·6 and 0·5 MJ/d, on the HP, NS, HC and HF treatments respectively ($F(3,21)$ 3·61; $P = 0·03$; SED 0·052). Subjects also consumed on average, approximately twice the weight ($F(3,21)$ 5·29; $P = 0·007$) and energy ($F(3,21)$ 4·44; $P = 0·014$) of salad garnish on the NS treatment

Table 1. Mean *ad libitum* and total (inclusive of snack) food, energy and nutrient intakes for eight men on each of four dietary treatments (NS, no snack; HP, high protein; HC, high carbohydrate; HF, high fat), together with the *F* ratios, standard errors of the differences between means and probabilities for the main effects

	Diet						
	HP	HC	HF	NS	Variance ratio *F*(3,21)	*P* value	SED
Ad libitum intake							
Weight (kg)	3·7	3·2	3·1	3·9	4·44	0·015	0·23
Energy (MJ)	11·7	11·7	12·2	13·9	5·35	0·007	0·66
Protein (MJ)	1·4	1·4	1·5	1·7	5·86	0·005	0·08
Fat (MJ)	4·7	4·7	4·9	5·5	4·48	0·014	0·28
Carbohydrate (MJ)	5·6	5·6	5·8	6·7	5·87	0·004	0·30
Total intake							
Weight (kg)	4·4	3·9	3·9	3·9	1·97	0·149	0·23
Energy (MJ)	14·3	14·1	14·8	13·9	0·55	0·654	0·63
Protein (MJ)	3·3	1·6	1·8	1·7	170·28	< 0·001	0·08
Fat (MJ)	5·0	5·0	6·8	5·5	19·50	< 0·001	0·27
Carbohydrate (MJ)	6·0	7·5	6·2	6·7	11·38	< 0·001	0·29

compared with the other three diets. There were no significant meal effects or diet × day interactions.

Subjective hunger, fullness and appetite

Mean daily hunger was not significantly affected by snacking or snack composition. Mean daily values were 37, 32, 30 and 34 (SED 2·7) mm on the NS, HP, HC and HF conditions respectively (F(3,18) 1·37; $P = 0·102$). However, subjects felt significantly more hungry at 12.00 hours on the NS condition relative to the other three diets. The average 12.00 hours values were 37, 26, 23 and 19 (SED 5·0) mm on the NS, HP, HC and HF conditions respectively (F(3,18) 4·42; $P = 0·017$). There was a significant difference between expressed 'desire to eat' at 12.00 hours, with values of 35, 23, 20 and 15 (SED 4·4) mm (F(3,18) 6·60; $P = 0·003$) respectively. This was also apparent for subjectively rated 'urge to eat', 'prospective consumption', 'thoughts of food' and fullness.

Subjectively rated fullness was significantly different between diets. The average 24 h values were 37, 41, 43 and 38 (SED 2·3) mm on the NS, HP, HC and HF conditions respectively (F(3,18) 3·55; $P = 0·0035$). Non-significant patterns for 24 h hunger were apparent for subjectively rated 'desire to eat', 'urge to eat', 'prospective consumption' and 'thoughts of food'. It should be noted that these values are the non-transformed square-root values. We give the non-transformed values in the text because the 100 mm scale is more familiar to most researchers.

Values for average subjectively rated pleasantness, rated 15 min after consuming main meals were 78, 72, 77 and 78 (SED 3·8) on the NS, HP, HC and HF conditions respectively, showing that the snack *v*. NS condition and the different snacks did not alter the perceived pleasantness of the *ad libitum* diet. There was, however, a significant meal effect, with subjects, on average, rating breakfast, lunch and dinner at 70, 79 and 81 (SED 1·3) mm (F(2,267) 36·80; $P < 0·001$) which was independent of the dietary treatment. Subjects preferred main meals to breakfast.

Body weight

There were no significant differences between diets in body-weight changes between days 3 and 9 of each run. The mean weight changes between days 3 and 9 were gains of 0·48 (SE 0·06) and 0·33 (SE 0·05) kg on the HP and HC diets and losses of 0·16 (SE 0·06) and 0·03 (SE 0·04) kg on the NS and HF diets. These weight changes were not significantly different from zero.

Discussion

Effect of snack v. *no-snack schedule on feeding behaviour*

Changes in the diurnal distribution of EI have been found to have little effect on the energy expenditure side of the energy equation. It has also been shown that meal frequency (at the same level of EI) does not affect RMR, diet-induced thermogenesis, energy expended in physical activity or total daily energy expenditure in men or women (Verboeket-van de Venne *et al*. 1993*a*,*b*). Snacking *v*. meal feeding for the same level of daily EI did affect the periodicity of substrate oxidation, inducing larger periodicity in carbohydrate and fat oxidation on the meal-feeding regimen (Verboeket-van de Venne & Westerterp, 1991). Meal-feeding induced larger rises in carbohydrate oxidation in the first few hours after a meal followed by a greater contribution of fat oxidation to energy expenditure. The oxidation of both nutrients on the snacking regimen was more constant.

Few controlled laboratory studies have examined whether simply altering the number of small, inter-meal ingestive events (snacking *per se*) affects total daily food intake and EI, although less controlled interventions have been conducted (Fabry *et al*. 1966; Yates *et al*. 1998). The present study found that incorporating three snacks (that were slightly less energy dense than the *ad libitum* diet) in inter-meal intervals led to good compensation at meal times, with no significant difference between total daily intakes. Subjects ate fewer meals and snacks during the *ad libitum* period on the snack conditions than on the NS condition, thus suggesting that meal size and meal frequency (i.e. snacking) tended to be reduced in order to compensate for the additional snacks. The results of this present study suggest that even under the constraints of a quantitative *ad libitum* feeding system (where subjects can only increase or decrease the amount of food they eat) feeding behaviour is flexible enough to compensate for mandatory increments to EI during the inter-meal period. Such flexibility in adapting feeding behaviour to altered feeding schedules has also been recorded in other species (Le Magnen, 1992; Forbes, 1995). These data are consistent with the results relating to subjective hunger, which showed that while subjects were hungrier at snack time on the NS condition, overall mean daily hunger and appetite scores were similar. These findings under carefully controlled conditions support the findings of animal studies and the intervention studies conducted by Fabry *et al*. (1966) in schoolchildren three decades ago, which suggest that animals and human subjects can adapt feeding behaviour to altered feeding schedules without severely disrupting EI. This does not mean that ingestion of commercially available foods, commonly termed snack foods, may not influence appetite and EI. Snack foods can differ from other foods in (1) energy density, (2) orosensory characteristics which may influence the hedonics of eating and (3) macronutrient composition.

Energy density of snack foods. Analysis of 342 foods commonly eaten as snacks (fruit, soft drinks, yoghurt, desserts, breads, cheese, cereals, confectionery, cakes, biscuits and savoury snacks) from the British food tables suggests that common snack foods tend to be energy-dense foods (RJ Stubbs, unpublished results). The average energy density of these snack foods is about 10 kJ/g (food category means range from 2·5 (fruit) to 22·0 kJ/g (savoury snacks)) compared with 3·8 kJ/g for the snack foods used in our present study. It is therefore possible that ingestion of more energy-dense foods will, transiently at least, elevate total daily EI. Conversely, ingesting snack foods which fall below the energy density of the foods that subjects normally eat, may produce transient decreases in EI (Yates *et al*. 1998).

Snack-related orosensory characteristics that may affect energy intake. There is evidence that the oro-sensory qualities of dietary fat and sugars may interact to influence the sensory stimulation to eat. Mela & Sachetti (1991) have suggested that preference for fat-related oro-sensory stimuli increases with the BMI of a study population. Drewnowski (1995) notes that it has been repeatedly shown that sugar–fat mixtures appear to exert a synergistic effect on the sensory pleasure response of human subjects. Green & Blundell (1996) have recently compared the effects of high-carbohydrate and high-fat sweet and savoury snacks on short-term intake. Ingestion of high-fat sweet snacks exerted a far greater effect on EI, which was independent of energy density, since EI were about twice those on any other treatment despite the fact that the energy density of the high-carbohydrate savoury snacks was higher. These considerations suggest that certain nutrient-based sensory stimuli may interact to affect EI, in the short term at least.

Macronutrient composition dependent and independent of energy density. Dietary fat tends to elevate the energy density of foods including that of snack foods. The present study suggested that changes in the macronutrient composition of snack foods which had the same, low energy density did not substantially affect energy or food intake, since subjects compensated accurately for the intervention. Clearly, daily nutrient intake was affected because subjects could not alter the composition of the *ad libitum* diet they were given. These results beg the question 'how would similar subjects respond to more realistic snack foods in real life?'. In a recent intervention study by the Leeds group (Lawton *et al*. 1998) high-fat and low-fat snacks that were either sweet or non-sweet were given to free-living university staff and students. The volunteers were required to ingest at least 25 % of their daily energy requirements from these snacks. The snack categories were sweet, low fat (mean energy density 15·7 kJ/g), sweet, high fat (21·5 kJ/g), non-sweet, low fat (14·9 kJ/g) and non-sweet, high fat (21·2 kJ/g). Subjects ate significantly more energy from both sweet than non-sweet categories, and within each taste category ate more energy from the high-fat snacks. This effect has also been demonstrated in other shorter term studies by the same group (Green & Blundell, 1996). However, total daily EI was not significantly altered either between these treatments or in comparing any of these treatments with pre-study intakes. The snack treatments did, however, significantly influence nutrient intake dependent on their composition. Thus, the high-fat snacks elevated the percentage of total daily EI from fat. Similarly, high-carbohydrate snacks elevated the percentage of energy derived from carbohydrates. Thus, lean men and women compensated energy, but not nutrient intake for the inclusion of high- and low-fat snacks into their diet under free-living conditions. These results are similar to those of the present study conducted under more artificial conditions, with snacks of a far lower energy density (3·8 kJ/g). Together these data suggest that snack intakes may invoke better energy compensation than manipulation of nutrient and energy content of meals, at least in lean men, and in the study of Lawton *et al*. (1998), lean men and women. The findings of these two studies suggest that in lean young adults, snack intake tends to fine-tune meal time EI to match energy requirements. However, different age groups, more sedentary and overweight subjects may not respond in the same manner.

Thus, while the inclusion of snack foods in short-term protocols may elevate EI at a given eating episode (Green *et al*. 1996), data from the present study and in a more real-life context (Lawton *et al*. 1998) suggest that over periods of several days, altering meal patterns *per se* does not drastically alter EI in lean young adults. These data suggest that altering the temporal distribution of EI in itself is not likely to lead to weight gain. However, different subjects may respond differently. Westerterp-Plantenga *et al*. (1994) have shown that habitual meal feeders do not compensate well for alterations in the energy density of specific meals while habitual snackers compensate more accurately. It is probable that as diet composition and sensory characteristics can interact to affect EI, so can diet composition and energy density, especially in certain groups of subjects.

Limitations of the present results

The experimental design (and hence conclusions arising from it) was subject to the following constraints. (1) It should be remembered that the subject's response in terms of food intake could only vary quantitatively. Selection of different foods, which varied in composition and/or energy density, was precluded. (2) The experimental environment of the Human Nutrition Unit allows great precision and accuracy with respect to dietary intakes and diet formulation, while maintaining, as far as possible, the naturalistic appearance, taste and texture of foods. However, these are not common, familiar or 'real' foods. Furthermore the energy density of the *ad libitum* diets was constant across food items. This does not occur in real life. Also the snacks were low in energy density compared with many common snack foods. Equal attention should be given to studies conducted in more naturalistic environments. (3) This experiment used eight lean, young men as the study population. It may be inappropriate to extrapolate these findings to other groups in the population such as women, older subjects or overweight subjects. (4) The present study was of a relatively short duration and caution should be exercised when extrapolating conclusions to longer term energy balance.

Conclusions

This study suggests that alteration of the temporal distribution of EI across the day, through the inclusion of relatively low energy dense mandatory snacks, leads to compensatory adjustments in *ad libitum* food intake and EI in normal-weight men. Differences in the composition of isoenergetic, isoenergetically dense snacks, consumed three times per day, did not affect food intake. However, under free-living conditions where subjects can also alter energy density and the composition of foods eaten and where some snack foods tend to be high in energy density, results may differ. Furthermore different types of people of different sex, age and activity patterns may respond differently.

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Appendix

Table 1. Mean mandatory food, energy and nutrient intakes of the high-protein (HP), high-carbohydrate (HC) and high-fat (HF) snacks used in the present study

Snack	Weight (g)	Energy (MJ)	Protein (MJ)	Fat (MJ)	Carbohydrate (MJ)
HP salad	241	0·87	0·64	0·12	0·11
HP pâté	183	0·84	0·64	0·08	0·12
HP yoghurt	247	0·85	0·60	0·13	0·12
HP total	671	2·56	1·88	0·33	0·35
HC salad	245	0·86	0·10	0·12	0·64
HC pâté	183	0·87	0·12	0·10	0·65
HC yoghurt	253	0·87	0·10	0·13	0·64
HC total	681	2·61	0·33	0·35	1·93
HF salad	251	0·89	0·11	0·67	0·11
HF pâté	187	0·85	0·11	0·62	0·12
HF yoghurt	248	0·87	0·11	0·64	0·12
HF total	686	2·60	0·33	1·92	0·35

Table 2. Recipes for the mandatory high-protein, high-carbohydrate and high-fat snacks used in the present study: example intake for a 10 MJ requirement

	High protein		High carbohydrate		High fat	
Snack	Food	Wt (g)	Food	Wt (g)	Food	Wt (g)
Salad	Canned tuna	66	Raw carrot	66	Mayonnaise	24
	Protifar*	21	Raw apple	50	Cucumber	82
	Garlic puree	2	Raisins	33	Carrot	45
	Tomato puree	6	Boiled rice	31	Celery	95
	Boiled peas	33	Raw celery	27	Canned tuna	20
	Broccoli	17	Salad cream	17	Apple	17
	Raw carrot	17	Canned tuna	18	Broccoli	4
	Reduced-fat cheese	12	Water	8		
	Cottage cheese	17	Cucumber	26		
	Cucumber	5	Broccoli	4		
	Celery	8				
	Canned sweetcorn	4				
	Water	74				
Pâté	Canned tuna	167	Canned tuna	8	Canned tuna	13
	Wholemeal bread	20	Sour cream	8	Wholemeal bread	17
	Cottage cheese	18	Low-fat yoghurt	12	Low-energy mayonnaise	18
	Greek yoghurt	9	Lemon juice	8	Avocado	23
			Instant potato	73	Cress	33
			Maxijule†	8	Mushrooms	74
			Sugar	4	Chilli powder	1
			Canned sweetcorn	24	Lemon juice	17
			Wholemeal bread	20	Instant potato	17
			Raw mushrooms	8		
			Onion	8		
			Boiled rice	8		
			Oxo cube	1		
Drink	Strawberries	16	Strawberries	25	Strawberries	11
	Raspberries	16	Raspberries	26	Raspberries	13
	Protifar*	42	Sugar	31	Gelatin	2
	Single cream	8	Milk	28	Canderel‡	2
	Canderel‡	2	Yoghurt	82	Soya milk	71
	Semi-skimmed milk	114	Crusha syrup	8	Yoghurt	17
	Water	114	Gelatin	1	Single cream	95
			Double cream	2	Water	100
			Water	99		

* Protein supplement; Protifar, Trowbridge, Wilts., UK.
† Carbohydrate supplement; Scientific Hospital Supplies International Ltd, Liverpool, Merseyside, UK.
‡ Low-energy sweetener; Monsanto plc, High Wycombe, Bucks., UK.

Table 3. The 3 d medium-fat rotating menu used as the standard *ad libitum* diet in the present study*

Meal	Day 1	Day 2	Day 3
Breakfast	Weetabix 600 g	Porridge 600 g	Ready Brek 600 g
Lunch	Vegetable stew 2 × 400 g	Pasta and lentil Bolognese 2 × 400 g	Sweet and sour chicken 2 × 400 g
Snacks (sweet)	Apricot fool 2 × 150 g	Strawberry fool 2 × 150 g	Raspberry fool 2 × 150 g
Snacks (soup)	Leek and potato 400 g	Cheesy potato 400 g	Sweetcorn 400 g
Milk shakes	Banana 300 g	Chocolate 300 g	Strawberry 300 g
Supper	Chicken curry 2 × 400 g	Chilli con carne 2 × 400 g	Wheat bake 2 × 400 g
Sweets	Chocolate blancmange 2 × 150 g	Blackcurrant fluff 2 × 150 g	Rhubarb and custard 2 × 150 g
Drinks	Ovaltine 350 g	Cocoa 350 g	Drinking chocolate 350 g
Soft drinks	Squash 1000 g	Squash 1000 g	Squash 1000 g
Milk allowance	Semi-skimmed 200 g	Semi-skimmed 200 g	Semi-skimmed 200 g
Canderel (sweetener)	2 g	2 g	2 g

* Garnish 1: 30 g cucumber, 40 g lettuce, 30 g tomato; garnish 2: 30 g green pepper, 20 g celery, 10 g cress, 40 g lettuce. Salt or pepper could be added to food to taste. Decaffeinated tea and coffee were available *ad libitum* and weighed and recorded before drinking. Additional *ad libitum* access to tap water was allowed.

Table 4. Energy and nutrient contents (MJ/100 g) of the foods making up the medium-fat diet consumed *ad libitum* by subjects in the present study

Food	Weight (g)	Energy (MJ)	Fat (MJ)	Carbohydrate (MJ)	Protein (MJ)
Weetabix	100	0·54	0·22	0·26	0·06
Porridge	100	0·53	0·22	0·25	0·06
Ready Brek	100	0·53	0·22	0·25	0·06
Vegetable stew	100	0·56	0·23	0·27	0·06
Pasta Bolognese	100	0·56	0·23	0·26	0·07
Sweet and sour chicken	100	0·61	0·25	0·28	0·08
Fruit fool	100	0·55	0·22	0·26	0·07
Leek and potato soup	100	0·55	0·23	0·25	0·07
Cheesy soup	100	0·55	0·23	0·25	0·07
Sweetcorn soup	100	0·51	0·22	0·22	0·07
Milk shake	100	0·56	0·22	0·27	0·07
Chicken curry	100	0·55	0·21	0·26	0·08
Chilli con carne	100	0·54	0·22	0·25	0·07
Wheat bake	100	0·54	0·22	0·26	0·06
Chocolate blancmange	100	0·56	0·22	0·27	0·07
Blackcurrant fluff	100	0·47	0·17	0·23	0·07
Milk jelly	100	0·55	0·22	0·26	0·07
Ovaltine	100	0·55	0·22	0·26	0·07
Cocoa	100	0·55	0·22	0·26	0·07
Drinking chocolate	100	0·55	0·22	0·26	0·07