Effects of added fruits and vegetables on dietary intakes and body weight in Scottish adults

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An increased consumption of fruits and vegetables (F&V) has been suggested as a way to limit, or even lower, energy and fat intakes. The present study examined the effects of incorporating F&V supplements into the diets of adults who reported consuming <240 g (three portions) of F&V per d on energy and fat intakes, and change in body weight, over 8 weeks using a randomised parallel design. Thirty-four males and twenty-eight females (age 42·6 (SD 11·1) years, BMI 23·7 (SD 2·7) kg/m^2) were each provided with supplements of 0, 300 or 600 g F&V per d. Food, nutrient and energy intakes were measured before, during and at the end of the supplementation period using 7 d weighed records. Mean daily energy intakes were not different among the three groups before ($P=0·151$) or during the supplementation periods ($P=0·407$), although changes in energy intakes over the study period tended to be more positive with increasing amounts of F&V supplements ($P=0·078$). There was no difference in changes of body weights during the study ($P=0·242$). Carbohydrate ($P<0·001$), sugar ($P<0·001$), fibre ($P<0·001$) and weight of food consumed ($P=0·022$) increased in the treatment groups. There were no significant differences, or changes, in fat intakes among the three groups. Consumption of mandatory F&V supplements for 8 weeks produced beneficial changes in diet composition, but did not result in lower reported energy or fat intakes, and did not result in loss of body weight.

Fruits and vegetables: Diet composition: Energy balance: Energy intake

Current WHO recommendations include consumption of at least 400 g fruits and vegetables (F&V) per d (World Health Organization, 1990), which have been incorporated into public health messages as variations on the 'five a day' goals. Few individuals in the UK, and especially Scotland, appear to be achieving this level of F&V consumption (Hunt *et al.* 2000; Agudo *et al.* 2002). It is widely believed that increasing intake of F&V will benefit a number of aspects of health, such as lowering the risk of CVD (Jenkins *et al.* 1979), enhancing colonic health (Haack *et al.* 1998) and the avoidance of excess energy intake (Holt *et al.* 1995; McCrory *et al.* 1999; Rolls & Bell, 1999). There may be other benefits in helping to lower fat intakes.

Fruits have a relatively high carbohydrate content. In addition to having a relatively high fibre content, F&V are low in protein and, with a few exceptions, low in fat. Over the last two decades there has been a growing acceptance that an increased intake of dietary fat is a risk factor for weight gain (Department of Health, 1995; International Obesity Task Force, 1998) (although most recently the acceptance of dietary fat's overriding importance in the development and maintenance of obesity has been questioned because in many areas population-wide fat intakes appear to have decreased as obesity has become more common). This has led public health and government bodies to propose a number of possible solutions to the perceived problems of excess fat intake in Western populations (Department of Health, 1995; International Food

Information Council Foundation, 1997; Leveille & Finlay, 1997; Sigman-Grant *et al.* 1998). The food industry has responded by producing lower-fat foods in the hope that they will assist in reducing dietary fat, and possibly energy intake, while maintaining sufficient sensory appeal that consumers will choose and ingest them. However, the few intervention studies that have examined this issue over several weeks or more have provided little evidence that increasing consumption of low-fat foods generally leads to any marked lowering of energy intake (Gatenby *et al.* 1995), except in individuals reporting initially high fat intakes (de Graaf *et al.* 1997). One possible explanation for this effect is that many low-fat foods are not necessarily low in energy density (Stubbs *et al.* 2001). F&V, however, are generally low in both fat and energy density. Furthermore, there is weak evidence that increased fibre intake has mild to moderate effects on motivation to eat and satiety (Levine & Billington, 1994; Delargy *et al.* 1997). It has been suggested that one of the most likely strategies to limit, or reduce, energy and fat intakes should be to increase F&V intake (Kant *et al.* 1992; Rolls *et al.* 1998; McCrory *et al.* 1999). However, this will only be effective if the additional F&V displace other, higher-fat and more energy-dense, foods from the diet; if not, the energy intake-lowering benefit will be lost.

The effect that increased F&V intake has on eating behaviour is also crucial from a policy point of view. The 'five a day' public health targets for F&V consumption have been made on the basis

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of health-related advice, but the effects on eating behaviour will have economic implications that may influence the likelihood of consumers achieving this minimum level of F&V intake.

It is therefore important to assess the impact of increasing F&V consumption on energy and nutrient intakes, and energy balance. The present study examined the effect on eating behaviour, and body weight (as a proxy measure of energy balance), when a fixed mandatory supplement of 0, 300 or 600 g F&V per d was provided to low F&V intake consumers over a period of 8 weeks. The study was designed to test the hypothesis that supplementing the diets of individuals having relatively low intakes of F&V would lower fat and energy intakes, and result in significant weight loss over an 8-week period.

Methods

Subjects

Forty-five couples (men and women living in the same household) were recruited by advertisement from Aberdeen, Scotland. To be eligible for the study, subjects had to be healthy, aged 20–65 years, not on a special or weight-reducing diet and have a BMI < 30 kg/m^2. Subjects also had to have a relatively low intake of F&V (three or fewer portions, < 240 g, per d excluding potatoes and allowing a maximum of one portion of each of fruit juice, and beans and pulses per d), which was assessed using 3 d food records completed before subjects were accepted onto the study (i.e. before week 0). Smokers were not excluded. Subjects gave their written informed consent before participation. The study was approved by the joint ethical committee of Grampian Health Board and the University of Aberdeen.

Study design

The forty-five men (weight 77·5 (SD 10·7) kg, height 1·77 (SD 0·07) m, age 44·2 (SD 11·6) years) and forty-five women (weight 63·2 (SD (8·4) kg, height 1·63 (SD 0·06) m, age 43·0 (SD (10·9) years) were enrolled into the study. Subjects received 0, 300 or 600 g F&V per d, using a 3 d rotating menu (Table 1), throughout weeks 1–8 of the study. Subjects, as couples, were allocated in the order that they were enrolled into the study to one of the three treatment groups in rotation. Thus, every third couple who started the study received the 0 g per d treatment. The supplements were investigator-weighed before being issued to the subjects and, to help

Table 1. Fruits and vegetables provided to volunteers as a 3 d rotating menu and average portion weights (g)

Supplement...	300 g	600 g
Day 1		
Tangerines	160	320
Apples	100	200
Cucumber	40	80
Day 2		
Oranges	160	320
Bananas	100	200
Carrots	40	80
Day 3		
Pears	125	250
Grapes	55	110
Tomatoes	120	240

reduce subject drop-out, were delivered three times per week to subjects' homes. Subjects were recruited as couples to keep the number of these visits to a practicable level.

Subjects were asked to return to the investigators any peel and core, etc. from the supplements, together with any uneaten supplements to encourage, and allow an estimation of, compliance. During the measurement weeks the recorded weight of supplements consumed was compared with the weight supplied. Subjects were instructed to include the F&V provided in their normal diet, but not how to do so. With the exception of the F&V intervention, subjects consumed their normal diets and were not given any funds to purchase foods, nor were they given any additional instruction as to how or what to eat.

The supplements provided a mean of 0·53 and 1·07 MJ/d, and 3·7 and 7·3 g NSP/d on the 300 and 600 g/d treatments respectively. The mean composition of the supplements was 89 % carbohydrate, 3 % fat and 7 % protein by energy.

Each subject was studied for three periods of 7 d each, which were before (week 0), during (week 4) and at the end (week 8) of the intervention. During this time measurements were made as detailed below.

Height, weight, body composition and resting metabolic rate

Height was measured at the beginning of the study on a portable stadiometer (Holtain Ltd, Crymych, Dyfed, UK) to the nearest 0·5 cm. Body weight was measured, after voiding and before eating, in the morning at the start and end of each 7 d measurement period using a digital platform scale (DIGI DS-410; CMS Weighing Equipment, London, UK) to the nearest 0·01 kg. Subjects wore the same light clothing and no shoes when being weighed.

Skinfold thickness measurements were taken at four sites (biceps, triceps, sub-scapular and supra-iliac) at week 0, and the equations of Durnin & Womersley (1974) were used to estimate body fat content.

RMR was measured at the beginning of week 0 under standardised conditions in fasted subjects by indirect calorimetry (Deltatrac II, MBM-200; Datex Instrumentarium Corporation, Helsinki, Finland), and using the equations of Elia & Livesey (1992).

Dietary intake data

Dietary data were collected using the 7 d weighed record method (Bingham, 1987). All weighing scales were calibrated with standard weights before use by the subjects. Food records were analysed using Diet5 for Windows (Univation Ltd, The Robert Gordon University, Aberdeen, UK), which uses UK food composition data (Holland et al. 1991) to calculate nutrient composition.

Implausible low energy reporters were characterised as subjects who, on one or more of the three food intake recording periods, reported low energy intakes ($< 1·2 \times$ RMR) and who did not lose weight over the 7 d period. Eleven men (24 %) and seventeen women (38 %) fell into this category and data from these subjects were removed from the analyses. It should be noted that the use of multiples of RMR to estimate energy requirements is arbitrary since the physical activity level can vary between 1·3 (extremely sedentary) and over $2 \times$ RMR (active) (Black et al. 1996). A relatively low value of $1·2 \times$ RMR was chosen so that body-weight changes over the 7 d period of the recorded food intake could also be used as a proxy of energy balance. Thus, it can be stated with reasonable certainty that subjects who ate

$< 1\cdot2 \times RMR$ and who did not lose weight would have had implausibly low energy intakes. However, some subjects with low energy intakes ($1\cdot3-1\cdot4 \times RMR$) may well have under-reported their energy intakes to some degree. A separate calculation was performed where energy intakes (relative to RMR) were low and subjects lost weight. The energy cost of weight loss, assuming that 75 % was adipose tissue and 25 % lean tissue, was averaged over 7 d using a value of $26\cdot2$ MJ/kg (Stubbs *et al.* 1998), and was then added to reported energy intake (on a daily basis) and the sum related to RMR. Thus, if a subject had a RMR of $7\cdot3$ MJ/d, $1\cdot5 \times RMR$ would be $10\cdot95$ MJ/d. If they reported an average intake of $8\cdot0$ MJ/d and lost $0\cdot6$ kg over the 7 d recording period, the energy cost of weight loss would be $(0\cdot6 \times 26\cdot2)/7 = 2\cdot25$ MJ/d. Reported energy intake ($8\cdot0$ MJ/d) + daily energy cost of weight loss ($2\cdot25$ MJ/d) amounts to $1\cdot4 \times RMR$ ($10\cdot25$ MJ/d). It was not considered reasonable to exclude subjects whose energy intake and energy cost of weight loss was $\geq 1\cdot4 \times RMR$ since they appear to have undereaten rather than under-reported.

Motivation-to-eat questionnaires

Subjects completed hourly hunger and appetite ratings during waking hours throughout the food intake recording periods, to record subjective sensations of hunger and motivation to eat, using a computerised visual analogue scale system, as previously described (Stratton *et al.* 1998). A rating of 0 corresponded with an extreme negative rating, and 100 with an extreme positive rating.

Dietary-restraint questionnaires

Dietary restraint and associated factors were assessed using the Dutch Eating Behaviour Questionnaire (van Strien *et al.* 1986) and the Three Factor Eating Inventory (Stunkard & Messick, 1985), which were completed before the week 0 food-recording period.

Statistical analysis

The removal of low energy reporters resulted in unequal numbers of subjects on each treatment, and the restricted maximum likelihood technique was therefore used, which can analyse unbalanced data (Patterson & Thompson, 1971). In these analyses, Wald tests are the equivalent of *F* tests and were used to assess the statistical significance of effects. Daily food, energy and macronutrient intakes were analysed with couple, sex and week as blocks, and with treatment (supplement type), sex and week as treatment factors.

The analyses of intakes were then modified to study the dose effect of the treatments, i.e. the relationship between the weight of supplements given and the food, energy and macronutrient intakes. Analyses were also performed to compare intakes both before and after the inclusion of supplements for all three treatments.

As there were no statistically significant within-group differences in energy or nutrient intakes reported during the week 4 and week 8 measurement periods, data from these two periods were combined.

A square-root transformation was applied to the motivation-to-eat ratings to ensure a normal distribution. Untransformed ratings are presented in the text.

All analysis was carried out using the GENSTAT 5 statistical package (Genstat 5 Committee of the Statistics Department, AFRC Institute of Arable Crops Research, Harpenden, UK).

Results

Subject characteristics

Subject characteristics are given in Table 2.

There were no statistically significant differences between groups for any of the characteristics given in Table 2, or for dietary restraint, emotionality, externality, hunger or disinhibition scores.

Energy and nutrient intakes

Intakes during week 0 and the supplementation periods, together with the changes relative to week 0, are given in Table 3. There were no significant differences in energy or macronutrient intakes among groups of subjects during week 0.

Energy, weight of food, and macronutrient intakes during the supplementation period were not significantly different among treatment groups. The changes in energy intake compared with week 0 were not significantly different among the three subject groups, although there was some evidence of an effect of the supplements on changes in energy intakes. Much of this appears to result from the decrease in energy intake in the control group. The diets of the three groups of subjects changed over the course of the study in directions that were consistent with the properties of the F&V supplements. Comparing intakes at weeks 4 and 8 to those of week 0 showed that the F&V supplements significantly increased sugar, carbohydrate and fibre intakes (as NSP), and weight of food and drinks consumed. There was also evidence of increased water and energy intake with increasing amounts of F&V supplements, although these differences failed to reach statistical significance.

The analyses of energy and nutrient intakes were repeated for all subjects. Inclusion of low energy reporters in the analysis had little overall effect. Some marginally significant results (excluding low energy reporters) became significant. These were between-group differences in changes of energy intake at weeks 4 and 8 compared with week 0 ($P = 0\cdot078$ and

Table 2. Subject characteristics at week 0

(Mean values and standard deviations)

Study group...	Control (*n* 17)		300 g (*n* 20)		600 g (*n* 25)	
	Mean	SD	Mean	SD	Mean	SD
Males (n)	10		10		14	
Females (n)	7		10		11	
Age (years)	39·4	9·6	44·3	11·2	43·4	11·8
Height (m)	1·73	0·11	1·70	0·09	1·71	0·12
Weight (kg)*	71·3	11·3	66·9	11·2	71·1	14·4
BMI (kg/m²)	23·8	2·6	23·1	2·5	24·2	3·1
Body fat (%)†	24·8	7·2	26·5	5·4	25·6	6·5

*At the start of the study.
†Estimated by skinfold thickness measurement; for details, see p. 497.

Table 3. Energy and nutrient intakes for week 0 and weeks 4 and 8 combined, and changes in intakes from week 0, for the three study groups, with standard errors of difference and Wald tests for between-group differences at week 1, weeks 4 and 8, and changes between week 0 and weeks 4 and 8*

(Mean values)

		Energy (MJ)	Protein (g)	CHO (g)	Fat (g)	Sugar (g)	Alcohol (g)	Weight (g)†	Fibre (g)	Water (g)
Control group (n 17)	Week 0	10.30	90.6	303.1	91.9	127.5	13.8	2730	13.6	1986
	Week 4 and 8	9.62	86.5	283.1	84.1	116.9	14.5	2599	14.2	1988
	Change	−0.68	−4.1	−20.0	−7.8	−10.6	0.7	−131	0.6	2
300 g group (n 20)	Week 0	8.97	81.7	256.9	74.1	102.5	12.4	2340	14.8	1829
	Week 4 and 8	8.29	75.9	263.8	64.9	123.1	11.0	2357	17.1	1882
	Change	−0.37	−5.3	6.9	−9.2	20.6	−1.4	17	2.3	53
600 g group (n 25)	Week 0	8.63	86.0	257.5	70.6	109.4	15.5	2532	15.1	1958
	Week 4 and 8	8.80	79.4	282.5	68.4	131.9	11.4	2680	20.4	2154
	Change	0.17	−2.9	25.0	−2.2	22.5	−4.1	148	5.4	196
Wald tests for between-group differences at week 0	χ^2	1.89	0.56	1.45	1.87	1.41	0.35	0.74	0.35	0.73
	SED	0.607	6.47	17.3	7.74	10.5	4.18	223	1.88	185
	P	0.151	0.569	0.235	0.154	0.243	0.705	0.475	0.706	0.481
Wald tests for between-group differences at weeks 4 and 8	χ^2	1.8	1.7	1.5	4.3	4.9	0.8	2.4	12.9	2.1
	SED	0.6	6.47	20	7.03	11.9	4.14	226	1.83	214
	P	0.407	0.427	0.472	0.117	0.086	0.670	0.301	0.002	0.350
Wald tests for changes between week 0 and weeks 4 and 8	χ^2	5.1	0.3	15.3	2	22.1	1.7	7.6	26.2	4.9
	SED	0.394	4.71	11.9	5.41	7.5	3.45	117	0.99	109
	P	0.078	0.861	<0.001	0.368	<0.001	0.427	0.022	<0.001	0.086

CHO, carbohydrate.

*For details of supplements, subjects and procedures, see Tables 1 and 2 and p. 497.

†Weight of food and drinks.

$P = 0.039$ excluding and including low energy reporters respectively), change in water intakes ($P = 0.086$ and $P < 0.001$) and between-group differences in total sugar intakes at weeks 4 and 8 ($P = 0.086$ and $P = 0.015$).

Intakes of fruits and vegetables

The reported supplement consumption was 97 and 89 % of that supplied on the 300 and 600 g/d intervention respectively.

Mean daily energy intakes from all F&V (i.e. including the supplementary F&V) and weight of F&V consumed are given in Table 4. Although the increase in F&V consumption was not as great as intended, because the supplements appear to have been partly displacing F&V that would have normally been consumed, there was still a graded increase in overall F&V consumption across the three groups.

Diet composition

Consumption of the F&V supplements produced a small but statistically significant effect on the contribution of protein in the diets, although this was mainly a result of differences in the contribution of protein in the diets of the control and 600 g/d groups at week 0. The percentage energy contribution of carbohydrate to the diets was significantly greater in the two supplemented groups at weeks 4 and 8, compared with week 0 (51.9 *v.* 47.7 % and 51.4 *v.* 47.8 % for the 300 and 600 g/d groups respectively), and the control group (47.8 and 47.6 % for week 0, and weeks 4 and 8 respectively; $P = 0.008$). However, there was no apparent dose effect; both the 300 and 600 g/d treatments produced a similar change in the percentage energy from carbohydrate.

Almost all of the carbohydrate provided by the supplements came from sugars, with the exception of that from the bananas, and this is reflected in the significantly greater percentage energy contribution of sugars to the diets of the supplemented groups (20.9, 19.0 and 19.7 % for the control, 300 and 600 g/d groups respectively during week 0, and 21.9, 25.2 and 24.8 % during weeks 4 and 8; $P = 0.013$). Again, there appeared to be no dose effect of the F&V supplements on the contribution of sugar to energy intake.

The effect of the F&V supplements on the percentage energy contribution from fat was small, just failed to reach significance, and there was no apparent dose effect of the supplements (33.2, 33.0 and 31.3 % for the control, 300 and 600 g/d groups

respectively during week 0, and 32.6, 28.9 and 29.4 % during weeks 4 and 8; $P = 0.051$).

There was no interaction of the F&V supplement and measurement period on the percentage of energy from alcohol, which was low for all groups during all measurement weeks, and lower than the estimated population average of 6 % energy intake (Bolton-Smith *et al.* 1992).

Change in body weight

There was no evidence of a difference in the change of body weight among the three groups of subjects over the 8-week supplement period ($+0.48$, -0.29 and -0.14 kg for the control, 300 and 600 g/d groups respectively; $F_{(2,53)} = 1.45$; $P = 0.242$).

Body weight was investigator-recorded and therefore was not subject to under-reporting errors. Change in body weight for all subjects (i.e. including low energy reporters) was $+0.10$, -0.07 and -0.47 kg for the control, 300 and 600 g/d groups respectively; $F_{(2,81)} = 4.21$; $P = 0.122$).

Motivation to eat

Increasing amounts of F&V supplements produced modest, but non-significant, reductions in motivation to eat, which were consistent with properties of the supplements. Average ratings during the two intervention measurement periods for the control, 300 and 600 g/d groups respectively were: for 'hunger', 35, 32 and 27 ($P = 0.076$); 'fullness', 50, 52 and 52 ($P = 0.700$); 'desire to eat', 40, 34 and 30 ($P = 0.052$); 'prospective consumption', 40, 37 and 33 ($P = 0.159$); 'urge to eat', 38, 32 and 29 ($P = 0.038$); 'thoughts of food', 35, 30 and 26 ($P = 0.082$).

Discussion

Energy intakes

The F&V supplements did not result in differences in reported energy intake among the three groups. This is consistent with two similar studies by Zino *et al.* (1997) and Cox *et al.* (1998), in which subjects increased their F&V consumption over 8-week periods following advice on how to do so. Changes in reported energy intake were not significantly different between intervention and control groups, and body weight increased by similar amounts in both groups ($+1.5$ and $+1.3$ kg for the control and intervention groups respectively; Cox *et al.* 1998), or did not

Table 4. Energy intake and total daily fruits and vegetable intakes, with standard errors of difference and Wald tests for treatment effects*

(Means values and standard deviations)

Study group	Week 0				Weeks 4 and 8			
	Energy (kJ)		Weight (g)		Energy (kJ)		Weight (g)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Control	430	290	188	110	470	290	207	127
300 g/d	520	350	222	151	920	300	451	143
600 g/d	550	330	245	162	1290	300	640	168
χ^2	0.700		0.800		38.9		42.4	
SED	100		46.0		93		47.1	
P	0.499		0.449		<0.001		<0.001	

*For details of supplements, subjects and procedures, see Tables 1 and 2 and p. 497.

change (Zino *et al.* 1997) over the 8 weeks. In the present study, and the studies of Zino *et al.* (1997) and Cox *et al.* (1998) an increased F&V consumption, achieved by different means, did not affect energy balance sufficiently to alter body weight over 8-week periods. Similarly, a self-reported increase of 1·4 portions of F&V per d, but over a 6-month period, did not alter body weight compared with a control group (+0·6 kg in both control and intervention groups; John *et al.* 2002).

The F&V supplements only contained an average of 1·07 and 0·53 MJ/d, and the lack of a significant difference in energy intake may reflect the limit of measurement error for self-recorded food intakes (Bingham, 1987). However, if the F&V supplements had elevated energy intake it was by an amount that was insufficient to significantly increase body weight over the supplementation periods. If the additional energy intake supplied by the F&V had not been compensated for, the 600 g/d group would have gained an average of about 1·8 kg over the 8 weeks, assuming an energy cost of weight gain of 33·2 MJ/kg (Forbes *et al.* 1982). The actual change in body weight, while not statistically significant, is in the opposite direction.

It has been argued that increasing the consumption of low-fat foods should result in lower fat intakes, a passive reduction in energy intake and a subsequent weight loss (Golay & Bobbioni 1997; Bray & Popkin, 1998; Kirk, 2000). It is further argued that this would be most effective when increasing consumption of foods that are both low-fat and low in energy density (Rolls *et al.* 1998; McCrory *et al.* 1999; Rolls & Bell, 1999). However, in the present and similar studies (Zino *et al.* 1997; Cox *et al.* 1998) subjects tended to compensate for any potential energy deficit created by increased consumption of F&V. Together these studies suggest that longer-term interventions that attempt to reduce dietary energy density and fat content do not promote a significant negative energy balance, at least in subjects not intending to lose weight. However, they may be protective against positive energy balances.

The F&V supplements did not displace fat from the diet. In de Graaf's study, reduced-fat foods had the greatest effect where there was the greatest opportunity to do so, in that there was only a lowering of overall fat and energy intakes in individuals who initially reported relatively high fat intakes (de Graaf *et al.* 1997). A similar effect was not apparent in the present study (data not presented). Initial fat intakes were relatively low (mean 32 % energy from fat) and subject numbers were small, especially when further divided into lower fat and higher fat consumers, and this may well have concealed any tendency for the F&V to have a greater effect on the diets of higher fat consumers.

Nutrient intakes

The F&V supplements produced several significant increases in sugar (and hence carbohydrate) intakes, fibre and water intake, and the total weight of food and drinks consumed. However, differences between the mean intakes of the three groups were not clear, fibre being the only significantly different nutrient. This lack of significant difference between groups is again likely to have been a consequence of a small dietary change compared with the relatively large measurement error of the method, and the biological variability in food intake itself. Again, changes in diet composition were similar to those reported by Zino *et al.* (1997) and Cox *et al.* (1998), where an increase in F&V consumption resulted in an increase in the percentage energy from carbohydrate and total sugars in the diet, and an increase in fibre intakes.

It has been suggested that sugar displaces fat from the diet through the action of the fat–sugar seesaw, and because fat is conducive to weight gain, sugar protects against the hyperphagia often associated with high-fat diets (Bolton-Smith & Woodward, 1994; Gibson, 1996). In line with the fat–sugar seesaw hypothesis (McColl, 1988; Gibney, 1990; Bolton-Smith & Woodward, 1994), the percentage energy contribution from fat tended to decrease as percentage energy from sugar increased with increasing dose of F&V supplements. Superficially, this could be considered as evidence of increased sugar consumption displacing fat from the diet. However, this is an artifact of expressing nutrient intakes as a percentage of total energy intake as the F&V increased the absolute amount of sugar, but did not decrease the absolute amount of fat in the diets. This is consistent with the studies of Mazlan (2001) and Whybrow (2002), where foods with high sugar contents did not displace fat from the diet, but produced a decrease in the percentage energy from fat.

Although the F&V supplements had little effect on lowering fat or energy intakes, it is likely that there were benefits for the two intervention groups that were not assessed here, such as increased antioxidant intakes and improved colonic health. These would only translate into long-term health benefits if F&V intakes remained elevated after provision of the free supplements had ended.

Dietary recommendations are to consume a variety of fruits and vegetables. Fruits differ from vegetables nutritionally and in how they tend to be consumed, which may influence eating patterns. Fruits are more likely than vegetables to be consumed as snacks (Anderson *et al.* 1998) with the possibility of displacing other, more energy- and fat-dense, snacks, although there was no evidence of this here. Conversely, the necessary preparation of most vegetables may involve the use of oils or fats, for example stir-frying or the use of fat-containing sauces. Subjects were not instructed on how to incorporate the supplements into their diets, and how they did so has not been considered in the present study. The supplements were chosen because they are commonly available and consumed within Scotland and were available throughout the year. The supplements provided were mainly fruits to aid subject compliance with the protocol as it was considered more likely that subjects would increase their intakes of fruits than vegetables. Marshall *et al.* (1994) concluded, from a consideration of Scottish consumers' attitudes and beliefs towards increasing their consumption of fruits and vegetables, that '... increasing consumption of fruit is likely to be more successful than increasing consumption of vegetables', because of their advantages of lack of necessary preparation and their portability. The results of the present study may have been different had a greater proportion of vegetables been used.

The present study did not assess the impact of increased F&V consumption on the financial implications for low-income earners, or on the practicable difficulties that may result from increased shopping frequency. The F&V were delivered, free of charge, to subjects. Low-income families are the ones that tend to have low intakes of F&V (Gibson *et al.* 1998), and are therefore likely to benefit most from an increased F&V consumption. But, to achieve the recommended intakes a family of five will need to purchase 14 kg F&V per week and, per unit of energy ingested, F&V are far more expensive than processed, convenience foods that are higher in fat and energy density.

The necessary frequent purchasing, and cost, of additional F&V are perceived as barriers to increasing consumption (Anderson *et al.* 1998). If F&V displace other foods from the diet then the cost of increasing F&V consumption will be less than if they are simply added to the diet, otherwise the cost of increasing F&V intake is likely to be prohibitive for low-income families.

Advantages and limitations of the study

An advantage of the present study was that subjects were weighed before and after each 7 d food intake measurement. Improbably low energy intakes could then be compared with changes in body weight. Energy intakes below $1.2 \times$ RMR, in the absence of weight loss, were deemed unreliable and were excluded for re-analysis of dietary patterns.

As with all studies there are a number of limitations in the present study that will have influenced the results and the interpretations thereof.

Use of an energy intake:RMR ratio to identify low energy reporters is arbitrary. All subjects appear to incorrectly report their food intake, and change their eating behaviour to a degree when recording their food intake (O'Reilly, 2001). Additionally, this method cannot identify those low energy reporters with a higher level of energy turnover, i.e. those with relatively high levels of physical activity.

Consumption of the F&V supplements was not recorded during the non-measurement weeks of the intervention, and it is possible that compliance was less complete than during the measurement weeks. Furthermore, it is possible that the non-blinded nature of the study encouraged the recording of F&V. However, recorded F&V intake did not change in the control group over the study ($P=0.454$).

Energy expenditure was not estimated during the study. It is possible that energy compensation was achieved partly through an increase in volitional exercise.

Subjects appeared to compensate well for the additional energy content of the F&V supplements; however, the time course of this compensation cannot be elucidated as the first assessment of supplemented dietary intake occurred after 3 weeks of supplementation.

Subjects were recruited on the basis of low F&V intakes as estimated from pre-study food records. Intakes of F&V during the pre-supplementation period suggested that mean intakes were higher than initially estimated.

The foods (rather than the individual macronutrients) that the F&V displaced from the diet (if any) were not considered.

The inclusion of a further intake recording period after the provision of the free F&V supplements had ended would have provided insights into whether subjects were able to incorporate more F&V into their diets.

Conclusion

The inclusion of a mandatory supplement of 300 or 600 g F&V per d into the diets of Scottish adults, reporting habitually low F&V intakes, over 8 weeks produced some beneficial changes in diet composition. Carbohydrate (from sugar) and fibre intakes increased in the two supplemented groups compared with the control group over the 8 weeks of the study. However, the supplements did not displace fat from the diet.

Subjects maintained energy balance throughout the intervention period to the extent that mean daily energy intakes were similar among the three intervention groups, and body weight did not change significantly over the study.

The results of the present study suggest that a mandatory F&V supplement of 300 and 600 g/d maintained energy intake and body-weight status over an 8-week period while producing beneficial changes in diet composition.

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