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REVIEW

# A review of the effectiveness of aspartame in helping with weight control

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**Summary**

Strategies to reverse the upward trend in obesity rates need to focus on both reducing energy intake and increasing energy expenditure. The provision of low- or reduced-energy-dense foods is one way of helping people to reduce their energy intake and so enable weight maintenance or weight loss to occur. The use of intense sweeteners as a substitute for sucrose potentially offers one way of helping people to reduce the energy density of their diet without any loss of palatability.

This report reviews the evidence for the effect of aspartame on weight loss, weight maintenance and energy intakes in adults and addresses the question of how much energy is compensated for and whether the use of aspartame-sweetened foods and drinks is an effective way to lose weight.

All studies which examined the effect of substituting sugar with either aspartame alone or aspartame in combination with other intense sweeteners on energy intake or bodyweight were identified. Studies which were not randomised controlled trials in healthy adults and which did not measure energy intakes for at least 24 h (for those with energy intakes as an outcome measure) were excluded from the analysis. A minimum of 24-h energy intake data was set as the cut-off to ensure that the full extent of any compensatory effects was seen. A total of 16 studies were included in the analysis. Of these 16 studies, 15 had energy intake as an outcome measure. The studies which used soft drinks as the vehicle for aspartame used between 500 and about 2000 ml which is equivalent to about two to six cans or bottles of soft drinks every day.

A significant reduction in energy intakes was seen with aspartame compared with all types of control except when aspartame was compared with non-sucrose controls such as water. The most relevant comparisons are the parallel design studies which compare the effects of aspartame with sucrose. These had an overall effect size of 0.4 standardised difference (SD). This corresponds to a mean reduction of about 10% of energy intake. At an average energy intake of 9.3 MJ/day (average of adult men and women aged 19–50 years) this is a deficit of 0.93 MJ/day (222 kcal/day or 1560 kcal/week), which would be predicted (using an energy value for obese

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tissue of 7500 kcal/kg) to result in a weight loss of around 0.2 kg/week with a confidence interval 50% either side of this estimate.

Information on the extent of compensation was available for 12 of the 15 studies. The weighted average of these figures was 32%. Compensation is likely to vary with a number of factors such as the size of the caloric deficit, the type of food or drink manipulated, and timescale. An estimate of the amount of compensation with soft drinks was calculated from the four studies which used soft drinks only as the vehicle. A weighted average of these figures was 15.5%.

A significant reduction in weight was seen. The combined effect figure of 0.2 SD is a conservative figure as it excludes comparisons where the controls gained weight because of their high-sucrose diet and the long-term follow-up data in which the aspartame groups regained less weight than the control group. An effect of 0.2 SD corresponds to about a 3% reduction in bodyweight (2.3 kg for an adult weighing 75 kg). Given the weighted average study length was 12 weeks, this gives an estimated rate of weight loss of around 0.2 kg/week for a 75-kg adult.

The meta-analyses demonstrate that using foods and drinks sweetened with aspartame instead of sucrose results in a significant reduction in both energy intakes and bodyweight. Meta-analyses both of energy intake and of weight loss produced an estimated rate of weight loss of about 0.2 kg/week. This close agreement between the figure calculated from reductions in energy intake and actual measures of weight loss gives confidence that this is a true effect. The two meta-analyses used different sets of studies with widely differing designs and controls. Although this makes comparisons between them difficult, it suggests that the final figure of around 0.2 kg/week is robust and is applicable to the variety of ways aspartame-containing foods are used by consumers.

This review has shown that using foods and drinks sweetened with aspartame instead of those sweetened with sucrose is an effective way to maintain and lose weight without reducing the palatability of the diet. The decrease in energy intakes and the rate of weight loss that can reasonably be achieved is low but meaningful and, on a population basis, more than sufficient to counteract the current average rate of weight gain of around 0.007 kg/week. On an individual basis, it provides a useful adjunct to other weight loss regimes.

Some compensation for the substituted energy does occur but this is only about one-third of the energy replaced and is probably less when using soft drinks sweetened with aspartame. Nevertheless, these compensation values are derived from short-term studies. More data are needed over the longer term to determine whether a tolerance to the effects is acquired.

To achieve the average rate of weight loss seen in these studies of 0.2 kg/week will require around a 220-kcal (0.93 MJ) deficit per day based on an energy value for obese tissue of 7500 kcal/kg. Assuming the higher rate of compensation (32%), this would require the substitution of around 330 kcal/day (1.4 MJ/day) from sucrose with aspartame (which is equivalent to around 88 g of sucrose). Using the lower estimated rate of compensation for soft drinks alone (15.5%) would require the substitution of about 260 kcal/day (1.1 MJ/day) from sucrose with aspartame. This is equivalent to 70 g of sucrose or about two cans of soft drinks every day.

**Keywords:** aspartame, energy intakes, intense sweeteners, meta-analysis, obesity, weight loss

## Introduction

Obesity is one of the major public health issues in the UK. Around two-thirds of the population are now overweight or obese, a quadruple increase in 25 years. If the present rates of increase continue, obesity will soon overtake smoking as the biggest cause of premature death in the UK. The economic costs of obesity and overweight are estimated to be between 6.6 and 7.4 billion pounds per year (Health Select Committee 2004). Obesity increases the risk of cancers, including breast cancer, endometrial cancer and colon cancer, diabetes, coronary heart disease, hypertension, insulin resistance, gall bladder disease and osteoarthritis. The psychological consequences of obesity are also huge and include anxiety, depression, low self-esteem and lack of confidence. Suicide is more common in obese people than normal-weight people (WHO 1998). Life expectancy is reduced by about 9 years in obese people, and by even more if they also smoke.

Strategies to reverse the upward trend in obesity rates need to focus on both reducing energy intake and increasing energy expenditure. The provision of low- or reduced-energy-dense foods is one way of helping people to reduce their energy intake and so enable weight maintenance or weight loss to occur. The use of intense sweeteners as a substitute for sucrose potentially offers one way of helping people to reduce the energy density of their diet without any loss of palatability. This is particularly the case with soft drinks as it is possible to reduce the energy content of the drink to practically zero as the energy content is almost entirely provided by sucrose or similar.

However, the usefulness of intense sweeteners as an aid to weight loss was questioned after reports that subjects had higher hunger ratings after drinking an aspartame-sweetened drink than after plain water (Blundell & Hill 1986). Blundell and Hill argued that any calorie savings achieved with intense sweeteners were false and were likely to be offset by increased energy intakes at subsequent meals. Although these findings were not replicated by other groups, the question of how much energy compensation occurs with the use of intense sweeteners has been the subject of much research.

This report reviews the evidence for the effect of aspartame on weight loss, weight maintenance and energy intakes in adults and addresses the question of how much energy is compensated for and whether the use of aspartame-sweetened foods and drinks is an effective way to lose weight.

## Methods and summary of data

All studies which examined the effect of substituting sugar with either aspartame alone or aspartame in combination with other intense sweeteners on energy intake or bodyweight in adults were identified. Reviews by Kanders *et al.* (1996), Rolls and Shide (1996), Drewnowski (1999), Vermunt *et al.* (2003) and Benton (2005) were used as a starting point for the search. Studies which were not randomised controlled trials in healthy adults and which did not measure energy intakes for at least 24 h (for those with energy intakes as an outcome measure) were excluded from the analysis. A minimum of 24-h energy intake data was set as the cut-off to ensure that the full extent of any compensatory effects was seen.

A total of 16 studies were included in the analysis. Of these 16 studies, 15 had energy intake as an outcome measure (Porikos *et al.* 1977, 1982; Foltin *et al.* 1988, 1990, 1992; Evans 1989; Mattes 1990; Tordoff & Alleva 1990; Naismith & Rhodes 1995; Blackburn *et al.* 1997; Gatenby *et al.* 1997; Lavin *et al.* 1997; Reid & Hammersley 1998; Raben *et al.* 2002; Van Wymelbeke *et al.* 2004) and 9 had weight loss (Porikos *et al.* 1977, 1982; Kanders *et al.* 1988, 1990; Tordoff & Alleva 1990; Naismith & Rhodes 1995; Blackburn *et al.* 1997; Gatenby *et al.* 1997; Reid & Hammersley 1998; Raben *et al.* 2002). The included studies show considerable variation in their design, study population, duration and type of control. The studies with energy intake as the outcome measure are summarised in Table 1 while those with weight loss are summarised in Table 2.

### Number of subjects

The largest trial had 163 subjects (Blackburn *et al.* 1997) while the two smallest trials had six and eight subjects (Porikos *et al.* 1977, 1982). Most trials had between 10–30 subjects.

**Table 1** Summary of studies with energy intakes as an outcome measure

| Reference | Number of subjects | Length of study | Intervention | Amount energy substituted | Reduction in energy intake | Calculated % compensation |
|---|---|---|---|---|---|---|
| **No energy restriction** | | | | | | |
| Evans (1989) | 16 post-obese women<br>5 occasional aspartame users<br>11 regular users | 3 weeks | Subjects were asked to exclude all aspartame-sweetened products from their diet | Average difference in baseline energy intakes was 194 kcal/day | Regular users increased energy intakes by 119 kcal/day *vs.* low users who decreased energy intakes by 204 kcal/day.<br>*ns* | Cannot be calculated |
| Foltin *et al.* (1992) | 6 normal-weight men | 7 × 2 days | Subjects in a metabolic ward were given foods which varied in energy, fat and carbohydrate content. The rest of their diet was freely chosen from a range of foods | Energy content of required foods ranged from 700 to 1700 kcal | –808 kcal/day* on low carbohydrate *vs.* high carbohydrate<br>–480 kcal/day* on low carbohydrate *vs.* control<br>*$P < 0.05$ | 16% |
| Foltin *et al.* (1990) | 6 normal-weight men | 4 × 3 days | Subjects in a metabolic ward were given four different lunches (low fat, low carbohydrate, high fat and high carbohydrate). All other food was freely chosen from a selection | Lunches provided either 431 or 844 kcal | –98 kcal/day on low calorie (carbohydrate) *vs.* high calorie (carbohydrate)<br>*ns* | 76% |
| Foltin *et al.* (1988) | 6 normal-weight men | 2 × 6 days | Subjects in a metabolic ward were provided with a variety of foods which could be eaten at any time. One-third of foods were substituted for low-calorie alternatives | About 500 kcal | No significant difference in energy intake when lower-calorie foods given.<br>Significant increase in energy intake when regular-calorie foods reintroduced | 100% |
| Gatenby *et al.* (1997) | 13/17/19 non-obese women | 10 weeks | Subjects in the intervention groups were instructed to use either reduced-fat or reduced-sugar foods instead of usual foods | Not reported | –276 (control) *vs.* –293 (reduced fat) *vs.* –329 kcal/day (reduced sugar)<br>*ns* | Cannot be calculated |
| Lavin *et al.* (1997) | 14 women | 1 day | Subjects were given 4 × 330 ml of drinks sweetened with either aspartame or sucrose or carbonated mineral water. Energy intakes were measured on the day and the following day. Half the subjects were told what they were drinking | 1.38 MJ | +1.7 MJ on aspartame compared with sucrose on the first day<br>*$P < 0.05$<br>+3.7 MJ on aspartame compared with sucrose over 2 days*$P < 0.05$ | 111% (over 2 days) |
| Mattes (1990) | 12 men<br>12 women | 5 days | Subjects were given breakfast cereals sweetened with either aspartame or sucrose or unsweetened. Half the subjects were aware of the composition (informed), the others were not (naïve) | Breakfasts were equicaloric | +189 kcal/day for informed aspartame group compared with naïve group<br>*ns*<br>+224 kcal/day for informed aspartame group compared with informed sucrose group<br>*ns* | 110% informed (knew what the composition was)<br>103% naïve (did not know what the composition was) |

**Table 1** *Continued*

| Reference | Number of subjects | Length of study | Intervention | Amount energy substituted | Reduction in energy intake | Calculated % compensation |
|---|---|---|---|---|---|---|
| Naismith and Rhodes (1995) | 10 normal-weight men | 2 × 10 days | Subjects were given meals and snacks sweetened with sucrose then sweeteners | 520 kcal | −260 kcal/day<br>*ns* | 42% |
| Porikos *et al.* (1982) | 6 normal-weight men | 2 × 12 days | Subjects in a metabolic ward were given foods sweetened with either aspartame or sucrose in a crossover study | About 900 kcal | −622 kcal/day* on aspartame *vs.* sucrose<br>$^*P < 0.01$ | 40% |
| Porikos *et al.* (1977) | 8 obese adults | 6 days on aspartame *vs.* 9 days on sucrose diet | Subjects in a metabolic ward were given foods sweetened with either aspartame or sucrose in a crossover study | 850 and 897 kcal on two aspartame periods | −762 and −452 kcal/day* on two aspartame periods *vs.* sucrose period<br>$^*P < 0.05$ | 50% |
| Raben *et al.* (2002) | 21/20 overweight men and women | 10 weeks | Overweight people were given foods and drinks sweetened with either sucrose or intense sweeteners to incorporate into their daily diet | 2.0–2.9 MJ | +1.6 MJ* (sucrose) *vs.* −0.45 MJ/day (sweetener)<br>$^*P < 0.05$ compared with baseline | 18% |
| Reid and Hammersley (1998) | 28 normal-weight men and women | 1 week | Subjects were given soft drinks sweetened with either aspartame or sucrose to incorporate into their daily diet | 200–400 kcal | Energy intakes less with aspartame drinks than with sucrose drinks but not significantly so | Energy difference between groups similar to difference in soft drinks |
| Tordoff and Alleva (1990) | 30 non-obese men and women | 3 × 3 weeks | Subjects were given 1150 g of soft drink (=4 cans) sweetened with either aspartame or high-fructose corn syrup (HFCS) or no soft drink in a crossover study | 530 kcal | −236* (women) and −154 kcal/day* (men) on aspartame *vs.* no soft drinks<br>+247* (women) and +374 kcal/day* (men) on HFCS *vs.* no soft drinks<br>$^*P < 0.05$ | 9% (women) and 1% (men) |
| Van Wymelbeke *et al.* (2004) | 12 men and 12 women | 4 weeks | Subjects drank 2 l of a soft drink sweetened with either sucrose or intense sweeteners and energy intake was measured on 2 successive days. This was repeated after 1 month of consuming either drink every day | 3.34 MJ | Session 1 – 2.98 MJ over 2 days**<br>Session 2 – 3.08 MJ over 2 days**<br>Session 3 – 3.20 MJ over 2 days** | 12% session 1<br>8% session 2<br>4% session 3 |
| **Weight loss diet** | | | | | | |
| Blackburn *et al.* (1997) | 163 obese women | 16 weeks<br>+1 year<br>+2 years | Intervention group were given, in addition to weight loss diet, aspartame-sweetened puddings or milkshakes and encouraged to use other aspartame-sweetened products | Not reported | *After 16 weeks*<br>−588 (aspartame) *vs.* −456 kcal/day (control)<br>*After 1 year*<br>−763 (aspartame) *vs.* −684 kcal/day (control)<br>*ns* | Cannot be calculated |

*Refers to *P*-value.
$^{**}P < 0.05$.
*ns*, non-significant.

**Table 2** Summary of data of studies with weight as an outcome measure

| Reference | Number of study | Length of study | Intervention | BMI | Weight change |
|---|---|---|---|---|---|
| **No energy restriction** | | | | | |
| Gatenby *et al*. (1997) | 13/17/19 | 10 weeks | Subjects in the intervention groups were instructed to use either reduced-fat or reduced-sugar foods instead of usual foods | <30 | No significant effect on bodyweight |
| Naismith and Rhodes (1995) | 10 men | 10 days | Subjects were provided with a diet from which about 500 kcal had been either covertly removed or added by the substitution of aspartame for sucrose | 22.6 and 21.4 | +0.13 kg for sucrose then aspartame<br>+0.44 kg for aspartame then sucrose<br>*ns* |
| Porikos *et al*. (1982) | 6 men | 2 × 12 days | Subjects in a metabolic ward were given foods sweetened with either aspartame or sucrose in a crossover study | 23.4 | +0.8* (sucrose) *vs.* –0.8 kg (aspartame)<br>*$P < 0.05$ compared with baseline |
| Porikos *et al*. (1977) | 8 | 6 days on aspartame *vs*. 9 days on sucrose diet | Subjects in a metabolic ward were given foods sweetened with either aspartame or sucrose in a crossover study | >30 | 104.3 (sucrose) *vs.* 104.0 kg (aspartame)<br>*ns* |
| Raben *et al*. (2002) | 21/20 | 10 weeks | Overweight people were given foods and drinks sweetened with either sucrose or intense sweeteners to incorporate into their daily diet | 28.0/27.6 | +1.6 (sucrose) *vs.* –1.0 kg* (sweetener)<br>*$P < 0.001$ compared with sucrose group |
| Reid and Hammersley (1998) | 28 | 1 week | Subjects were given soft drinks sweetened with either aspartame or sucrose to incorporate into their daily diet | Men 22.5/25.0<br>Women 23.4/23.5 | No significant effect on weight |
| Tordoff and Alleva (1990) | 30 | 3 × 3 weeks | Subjects were given 1150 g of soft drinks (=4 cans) sweetened with either aspartame or high-fructose corn syrup (HFCS) or no soft drinks in a crossover study | 25.4 (women)<br>25.1 (men) | +0.25 (women) and –0.47 kg* (men) on aspartame *vs.* no soft drinks<br>+0.97* (women) and +0.52 kg (men) on HFCS *vs.* no soft drinks<br>*$P < 0.05$ |
| **Weight loss diets** | | | | | |
| Blackburn *et al.* (1997) | 163 | 16 weeks<br>+1 year<br>+2 years | Intervention group were given, in addition to weight loss diet, aspartame-sweetened puddings or milkshakes and encouraged to use other aspartame-sweetened products | Aspartame 37.4<br>Control 37.2 | *After 16 weeks*<br>–9.9 (aspartame) *vs.* –9.8 kg (control)<br>*After 1 year*<br>+2.6* (aspartame) *vs.* +5.4 kg (control)<br>*After 2 more years* (net weight loss)<br>–5.1* (aspartame) *vs.* 0 kg (control)<br>*$P < 0.05$ compared with control |
| Kanders *et al.* (1988, 1990) | 59 (13 men; 46 women) | 12 weeks | Intervention group were given, in addition to weight loss diet, low-calorie, aspartame-sweetened puddings or milkshakes and encouraged to use diet drinks etc | Men 37/38<br>Women 36/38 | *After 12 weeks*<br>Men<br>–23.0 (intervention) *vs.* –27.0 lbs (control)<br>Women<br>–16.5 (intervention) *vs.* –12.8 lbs (control)<br>*After 1 year*<br>Inverse association between aspartame and weight regain in men but not in women |

*Refers to *P*-value.
BMI, body mass index; *ns*, non-significant.

### Length of trials

The longest trial had an intervention period of 19 weeks, and then followed up subjects for 3 years (Blackburn *et al.* 1997) while the shortest trial had an intervention period of only 1 day (Lavin *et al.* 1997). Seven trials had an intervention period less than 1 week while three trials lasted for 10 or 12 weeks.

### Body mass index

Subjects in three of the trials were obese with body mass index over 30 kg/m$^2$ (Porikos *et al.* 1977; Kanders *et al.* 1988; Blackburn *et al.* 1997). Two of these trials were weight loss trials where average body mass indices were around 37 kg/m$^2$. The other trials were in normal-weight or overweight people.

### Energy-restricted diet

Two trials tested the effectiveness of aspartame-containing products in people on an energy-restricted diet, who were trying to lose weight (Kanders *et al.* 1988; Blackburn *et al.* 1997). The other trials compared the effect of substituting foods and drinks containing aspartame/intense sweeteners for similar foods containing sugar in an *ab libitum* diet.

### Setting

The studies were carried out in both metabolic ward situations and in the free-living population. Some of the studies in metabolic wards allowed subjects to determine the amount of food they consumed from a platter of foods offered to them (Porikos *et al.* 1977, 1982) while other studies allowed them to select the food they wanted from a list of available foods (Foltin *et al.* 1988, 1990, 1992). Studies in free-living populations either gave subjects daily food supplements (Mattes 1990; Raben *et al.* 2002), provided meals on site (Naismith & Rhodes 1995) or told subjects to replace items in their diet with reduced sugar versions of their normal foods (Gatenby *et al.* 1997).

### Intervention vehicle

Four trials used soft drinks only as the vehicle for aspartame substitution. In one trial (Tordoff & Alleva 1990), subjects were required to drink the equivalent of four bottles (1135 g/day) of soft drinks each day while in another (Reid & Hammersley 1998), subjects were recruited on the basis of habitually drinking at least two bottles (250 ml each) of soft drinks a day. In the study by Van Wymelbeke *et al.* (2004), subjects were required to drink 2 l of a beverage on the study days while those in the study by Lavin *et al.* (1997) were given four cans (330 ml) of lemonade to drink at defined times during the day. In a fifth trial (Raben *et al.* 2002), 80% by weight of the substituted foods were given as soft drinks as this reflects the distribution of the population's intake of intense sweeteners. The average intake of soft drinks in this study was 1285 g/day.

The other trials used breakfast cereals (Mattes 1990) or selections of commercially available foods and drinks sweetened with aspartame (Porikos *et al.* 1977, 1982; Kanders *et al.* 1988; Blackburn *et al.* 1997) or a mixture of intense sweeteners (Foltin *et al.* 1988, 1990, 1992; Naismith & Rhodes 1995; Gatenby *et al.* 1997; Raben *et al.* 2002).

### Amount of food or energy substituted

This information was not always reported, nor was it reported in a similar way in each study. Some studies reported the amount of food that had been substituted while others reported the amount of sucrose or the percentage of energy substituted by aspartame products.

The studies which used soft drinks as the vehicle for aspartame used between 500 and about 2000 ml which is equivalent to about two to six cans or bottles of soft drinks every day. One study reported that about 2000 g of food per day was substituted for aspartame-containing foods (Porikos *et al.* 1977) while another reported that about 25% of energy was substituted (Porikos *et al.* 1982). The amount of energy substituted by aspartame ranged from about 200 kcal/day (0.84 MJ) (Reid & Hammersley 1998) to about 1000 kcal/day (4.2 MJ) (Foltin *et al.* 1992).

### Controls

The choice of control has an important effect on the outcome of the study and the relevance of the control diet to the 'normal' diet is open to question in many of the studies. For a number of studies, the control diet involved the addition of a large amount of sucrose-containing foods which did not reflect the subjects' previous diets and on which subjects gained weight (Porikos *et al.* 1977, 1982).

Whether the control period was before or after the aspartame period also has an effect on the outcome. Ten studies had a parallel sucrose-containing control while five studies compared aspartame with sucrose before and/or after (Porikos *et al.* 1977, 1982; Foltin *et al.*

1988; Evans 1989; Naismith & Rhodes 1995). Three studies also had an additional control of carbonated mineral water (Lavin *et al*. 1997), plain cereal (Mattes 1990) or no soda (Tordoff & Alleva 1990). In a number of studies, comparisons were also made with baseline values (Mattes 1990; Foltin *et al*. 1992; Raben *et al*. 2002).

## Results of meta-analysis

### Energy intakes

The 15 studies with energy intake as an outcome measure were subjected to a meta-analysis to calculate the combined effect (expressed as the standardised difference or SD) of all the studies together (Fig. 1). Effect sizes for each study were computed from the sample sizes, and either group means and standard deviation or *P*-values. Data presentation lacked statistical detail in a few studies, requiring standard deviations to be calculated or imputed. Studies varied in their design, subjects and types of control, so we used a random effects model (which allows that the true effect might differ from study to study) rather than a fixed effect model (which assumes that the true effect is the same for all studies). Hedges' adjustment was used, which gave a more conservative estimate of effect size. The plots illustrate the size and direction of effect for each study and the overall effect of all studies combined, with 95% (lower and upper) confidence intervals. All analyses were performed using the software package Comprehensive Meta-analysis (Biostat Inc., Englewood, NJ, USA). The studies were analysed according to the type of controls as this affected the results. The different controls were baseline diet, parallel sucrose control, non-sucrose control (*e.g.* water) or the reintroduction of sucrose. The effect of substituting aspartame-sweetened drinks with each of these controls is shown in Table 3.

A significant reduction in energy intakes was seen with aspartame compared with all types of control except when aspartame was compared with non-sucrose controls such as water.

The most relevant comparisons are the parallel design studies which compare the effects of aspartame with sucrose. These had an overall effect size of 0.4 SD. As the coefficient of variation of energy intake is around 25%, this corresponds to a mean reduction of about 10% of energy intake. At an average energy intake of 9.3 MJ/day (average of adult men and women aged 19–50 years) this is a deficit of 0.93 MJ/day (222 kcal/day or 1560 kcal/week), which would be predicted (using an energy value for obese tissue of 7500 kcal/kg) to result in a weight loss of around 0.2 kg/week with a confidence interval 50% either side of this estimate.

**Table 3** Summary of meta-analysis of energy intake

| Type of control (number of study outcomes) | *P*-value | Effect (SD) | 95% confidence limits | |
|---|---|---|---|---|
| | | | Lower | Upper |
| Baseline (8) | 0.017 | 0.58 | 0.10 | 1.05 |
| Non-sucrose control (7) | 0.377 | 0.18 | –0.22 | 0.58 |
| Sucrose after (5) | 0.000 | 1.14 | 0.52 | 1.76 |
| Sucrose parallel (12) | 0.033 | 0.40 | 0.03 | 0.77 |
| All studies (32) | 0.000 | 0.47 | 0.24 | 0.70 |

SD, standardised difference.

The strongest effect was found for comparisons in which the aspartame/low-sugar period was followed by a normal/high-sucrose diet (effect size > 1 SD). This suggests that increases in energy intake are less well compensated than decreases in energy intake.

### Average level of compensation

Compensation is the explanation for the difference between the theoretical energy intake and the actual energy intake in any study. The extent of compensation that occurred in the different studies was not reported for all studies, although it could be calculated for some studies from information given in the paper. Information on the extent of compensation was available for 12 of the 15 studies. The weighted average of these figures was 32% although they ranged from 1% to 111% (see Table 1). This estimate agrees well with the value of 36% for solid food calculated by Mattes (1996) in a meta-analysis of 42 studies.

Compensation is likely to vary with a number of factors such as the size of the caloric deficit, the type of food or drink manipulated, and timescale. An estimate of the amount of compensation with soft drinks was calculated from the four studies which used soft drinks only as the vehicle (Tordoff & Alleva 1990; Lavin *et al*. 1997; Reid & Hammersley 1998; Van Wymelbeke *et al*. 2004). A weighted average of these figures was 15.5%. This agrees with suggestions by other authors that compensation is likely to be less where the substitution vehicle is a liquid. This is because energy obtained from liquids is less satisfying than energy from solid foods, making it easier to overconsume energy when drinking liquids than when eating solids (Beridot-Therond *et al*. 1998; Van Wymelbeke *et al*. 2004).

| Comparison group (number of studies) | | Study authors | Significance of effect | Effect size (SD) | Confidence limits (95%) of effect | | Study duration (weeks) |
|---|---|---|---|---|---|---|---|
| | | | P-Value | | Lower | Upper | |
| | Base | Foltin *et al.*, 1988 | 1.000 | 0.000 | −1.286 | 1.286 | <1 |
| | Base | Foltin *et al.*, 1992 | 0.027 | 1.380 | −0.117 | 2.877 | <1 |
| | Base | Porikos *et al.*, 1982 | 0.010 | 1.689 | 0.097 | 3.281 | 1 |
| | Base | Porikos *et al.*, 1977 | 0.010 | 1.407 | 0.171 | 2.634 | 1 |
| | Base | Mattes, 1990 | 0.795 | 0.104 | −0.744 | 0.951 | <1 |
| | Base | Mattes, 1990 | 0.736 | −0.135 | −0.982 | 0.713 | <1 |
| | Base | Naismith & Rhodes, 1995 | 0.020 | 1.093 | 0.070 | 2.116 | 2 |
| | Base | Raben *et al.*, 2002 | 0.534 | 0.194 | −0.447 | 0.836 | 10 |
| **Fixed** | **Base (8)** | | **0.006** | **0.467** | **0.139** | **0.795** | |
| **Random** | **Base (8)** | | **0.017** | **0.578** | **0.103** | **1.053** | |
| | Other | Mattes, 1990 | 0.516 | −0.260 | −1.111 | 0.591 | <1 |
| | Other | Mattes, 1990 | 0.614 | 0.202 | −0.648 | 1.051 | <1 |
| | Other | Lavin *et al.*, 1997 | 0.050 | −0.754 | −1.563 | 0.054 | <1 |
| | Other | Tordoff & Alleva, 1990 | 0.050 | 0.952 | −0.118 | 2.021 | 3 |
| | Other | Tordoff & Alleva, 1990 | 0.050 | 0.612 | −0.028 | 1.252 | 3 |
| | Other | Tordoff & Alleva, 1990 | 0.379 | 0.406 | −0.606 | 1.418 | 3 |
| | Other | Tordoff & Alleva, 1990 | 0.476 | 0.218 | −0.408 | 0.843 | 3 |
| **Fixed** | **Other (7)** | | **0.207** | **0.184** | **−0.103** | **0.472** | |
| **Random** | **Other (7)** | | **0.377** | **0.180** | **−0.221** | **0.581** | |
| | Sucrose after | Porikos *et al.*, 1977 | 0.010 | 1.689 | 0.097 | 3.281 | 1 |
| | Sucrose after | Porikos *et al.*, 1982 | 0.010 | 1.689 | 0.097 | 3.281 | 1 |
| | Sucrose after | Foltin *et al.*, 1988 | 0.020 | 1.473 | −0.051 | 2.997 | <1 |
| | Sucrose after | Naismith & Rhodes, 1995 | 0.050 | 1.505 | −0.655 | 3.664 | 2 |
| | Sucrose after | Evans, 1989 | 0.364 | 0.381 | −0.518 | 1.281 | 3 |
| **Fixed** | **Sucrose after (5)** | | **0.000** | **1.081** | **0.521** | **1.641** | |
| **Random** | **Sucrose after (5)** | | **0.000** | **1.137** | **0.518** | **1.755** | |
| | Sucrose parallel | Van Wymelbeke *et al.*, 2004 | 0.001 | 0.998 | 0.379 | 1.617 | <1 |
| | Sucrose parallel | Mattes, 1990 | 0.660 | −0.176 | −1.024 | 0.673 | <1 |
| | Sucrose parallel | Mattes, 1990 | 0.090 | −0.699 | −1.576 | 0.178 | <1 |
| | Sucrose parallel | Lavin *et al.*, 1997 | 0.010 | −1.020 | −1.853 | −0.186 | <1 |
| | Sucrose parallel | Foltin *et al.*, 1992 | 0.016 | 1.542 | −0.003 | 3.087 | <1 |
| | Sucrose parallel | Foltin *et al.*, 1990 | 0.758 | 0.169 | −1.121 | 1.458 | <1 |
| | Sucrose parallel | Reid & Hammersley, 1998 | 0.217 | 0.473 | −0.333 | 1.280 | 1 |
| | Sucrose parallel | Tordoff & Alleva, 1990 | 0.011 | 0.812 | 0.161 | 1.463 | 3 |
| | Sucrose parallel | Tordoff & Alleva, 1990 | 0.057 | 0.923 | −0.142 | 1.988 | 3 |
| | Sucrose parallel | Gatenby *et al.*, 1997 | 0.137 | 0.536 | −0.213 | 1.286 | 10 |
| | Sucrose parallel | Raben *et al.*, 2002 | 0.002 | 1.015 | 0.340 | 1.690 | 10 |
| | Sucrose parallel | Blackburn *et al.*, 1997 | 0.015 | 0.435 | 0.081 | 0.789 | 19 |
| **Fixed** | **Sucrose parallel (12)** | | **0.000** | **0.439** | **0.243** | **0.634** | |
| **Random** | **Sucrose parallel (12)** | | **0.033** | **0.403** | **0.034** | **0.773** | |
| **Fixed** | **Combined (32)** | | **0.000** | **0.425** | **0.285** | **0.564** | |
| **Random** | **Combined (32)** | | **0.000** | **0.470** | **0.244** | **0.696** | |

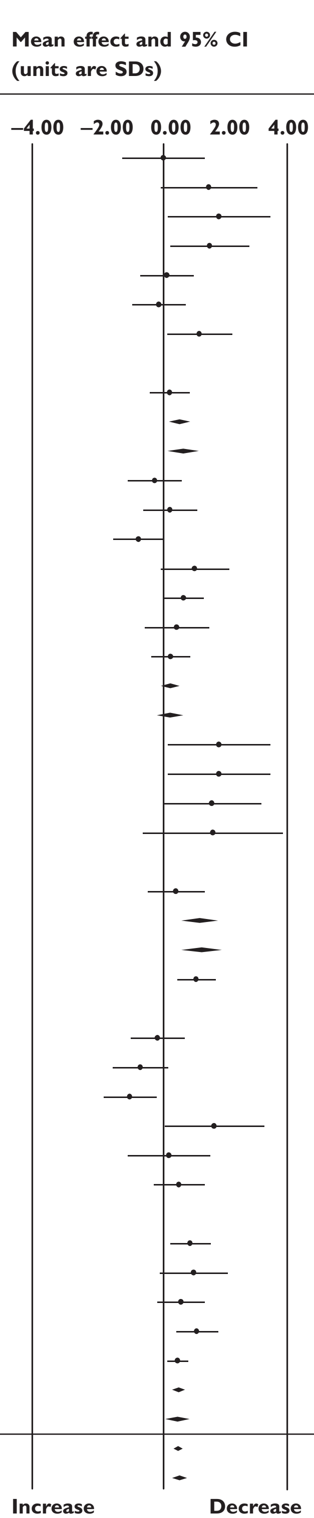


**Figure 1** Meta-analysis of studies of energy reduction with sweetener *vs.* other regime (subgroup analysis). CI, confidence intervals; SD, standardised difference.

| Comparison group (number of studies) | | Study authors | Significance of effect | Effect size (SD) | Confidence limits (95%) of effect | | Mean effect and 95% CI (units are SDs) | Study duration (weeks) |
|---|---|---|---|---|---|---|---|---|
| | | | ***P*-Value** | | **Lower** | **Upper** | **−4.00 −2.00 0.00 2.00 4.00** | |
| | Base | Porikos *et al.*, 1982 | 0.100 | 0.966 | −0.428 | 2.360 | | 1 |
| | Base | Porikos *et al.*, 1977 | 0.981 | 0.011 | −1.061 | 1.084 | | 1 |
| | Base | Naismith & Rhodes, 1995 | 0.710 | −0.162 | −1.103 | 0.780 | | 2 |
| | Base | Raben *et al.*, 2002 | 0.087 | 0.545 | −0.109 | 1.198 | | 10 |
| **Fixed** | **Base (4)** | | **0.135** | **0.328** | **−0.104** | **0.761** | | |
| **Random** | **Base (4)** | | **0.144** | **0.326** | **−0.114** | **0.767** | | |
| | Other | Tordoff & Alleva, 1990 | 0.564 | −0.265 | −1.269 | 0.740 | | 3 |
| | Other | Tordoff & Alleva, 1990 | 0.050 | 0.612 | −0.028 | 1.252 | | 3 |
| **Fixed** | **Other (2)** | | **0.199** | **0.342** | **−0.185** | **0.869** | | |
| **Random** | **Other (2)** | | **0.574** | **0.245** | **−0.621** | **1.110** | | |
| | Sucrose after | Porikos *et al.*, 1982 | 0.050 | 0.817 | −0.070 | 1.705 | | |
| | Sucrose after | Porikos *et al.*, 1977 | 0.050 | 1.014 | −0.146 | 2.174 | | 1 |
| | Sucrose after | Naismith & Rhodes, 1995 | 0.135 | 1.063 | −0.893 | 3.019 | | 2 |
| **Fixed** | **Sucrose after (3)** | | **0.005** | **0.919** | **0.295** | **1.542** | | |
| **Random** | **Sucrose after (3)** | | **0.005** | **0.919** | **0.295** | **1.542** | | |
| | Sucrose parallel | Reid & Hammersley, 1998 | 1.000 | 0.000 | −0.793 | 0.793 | | 1 |
| | Sucrose parallel | Tordoff & Alleva, 1990 | 0.010 | 1.310 | 0.182 | 2.439 | | 3 |
| | Sucrose parallel | Tordoff & Alleva, 1990 | 0.116 | 0.486 | −0.148 | 1.120 | | 3 |
| | Sucrose parallel | Raben *et al.*, 2002 | 0.001 | 1.090 | 0.408 | 1.772 | | 10 |
| | Sucrose parallel | Gatenby *et al.*, 1997 | 0.175 | 0.487 | −0.260 | 1.234 | | 10 |
| | Sucrose parallel | Kanders *et al.*, 1988 | 0.102 | 0.490 | −0.122 | 1.102 | | 12 |
| | Sucrose parallel | Kanders *et al.*, 1988 | 0.623 | −0.292 | −1.721 | 1.137 | | 12 |
| | Sucrose parallel | Blackburn *et al.*, 1997 | 0.919 | 0.016 | −0.294 | 0.325 | | 19 |
| | Sucrose parallel | Kanders *et al.*, 1990 | 0.040 | 0.613 | 0.004 | 1.223 | | 52 |
| | Sucrose parallel | Blackburn *et al.*, 1997 | 0.143 | 0.318 | −0.117 | 0.752 | | 71 |
| | Sucrose parallel | Blackburn *et al.*, 1997 | 0.028 | 0.487 | 0.043 | 0.930 | | 175 |
| **Fixed** | **Sucrose parallel (11)** | | **0.000** | **0.358** | **0.194** | **0.523** | | |
| **Random** | **Sucrose parallel (11)** | | **0.000** | **0.420** | **0.194** | **0.645** | | |
| **Fixed** | **Combined (20)** | | **0.000** | **0.385** | **0.242** | **0.528** | | |
| **Random** | **Combined (20)** | | **0.000** | **0.426** | **0.251** | **0.601** | | |

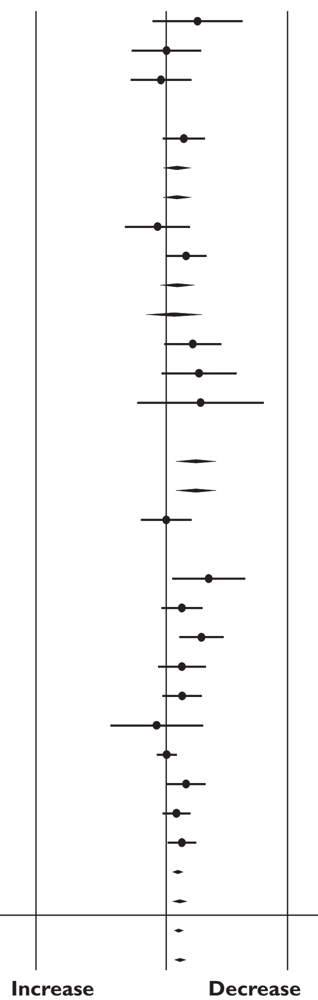


**Figure 2** Meta-analysis of studies of weight loss with sweetener *vs.* sucrose regime (all studies). CI, confidence intervals; SD, standardised difference.

## Weight loss

A meta-analysis of the 9 studies with weight loss as an outcome measure was also conducted to calculate the combined effect of aspartame on weight loss. The analysis was conducted in three stages. The first stage used all weight outcomes including follow-up weights, the second excluded studies in which the control group gained weight and the third excluded follow-up periods as well. Forrest plots for these analyses are shown in Figures 2–4. The combined effects of the results for the different analyses are shown in Table 4.

A significant reduction in weight was seen for all three analyses. The final combined effect figure of 0.221 SD (from Fig. 4) is a conservative figure as it excludes comparisons where the controls gained weight because of their high-sucrose diet and the long-term follow-up data in which the aspartame groups regained less weight than the control group. This gave the appearance of an increasing weight loss with aspartame.

As the coefficient of variation for bodyweight calculated from the larger studies was 15%, an effect of 0.2 SD corresponds to about a 3% reduction in bodyweight (2.3 kg for an adult weighing 75 kg). Given the

| | Study authors | Significance of effect | Effect size (SD) | Confidence limits (95%) of effect | | Study duration (weeks) | Type of control |
|---|---|---|---|---|---|---|---|
| | | *P*-Value | | Lower | Upper | | |
| | Reid & Hammersley, 1998 | 1.000 | 0.000 | −0.793 | 0.793 | 1 | Sucrose parallel |
| | Tordoff & Alleva, 1990 | 0.564 | −0.265 | −1.269 | 0.740 | 3 | Other |
| | Tordoff & Alleva, 1990 | 0.050 | 0.612 | −0.028 | 1.252 | 3 | Other |
| | Raben *et al*., 2002 | 0.087 | 0.545 | −0.109 | 1.198 | 10 | Base |
| | Gatenby *et al*., 1997 | 0.175 | 0.487 | −0.260 | 1.234 | 10 | Sucrose parallel |
| | Kanders *et al*., 1988 | 0.102 | 0.490 | −0.122 | 1.102 | 12 | Sucrose parallel |
| | Kanders *et al*., 1988 | 0.623 | −0.292 | −1.721 | 1.137 | 12 | Sucrose parallel |
| | Blackburn *et al*., 1997 | 0.919 | 0.016 | −0.294 | 0.325 | 19 | Sucrose parallel |
| | Kanders *et al*., 1990 | 0.040 | 0.613 | 0.004 | 1.223 | 52 | Sucrose parallel |
| | Blackburn *et al*., 1997 | 0.143 | 0.318 | −0.117 | 0.752 | 71 | Sucrose parallel |
| | Blackburn *et al*., 1997 | 0.028 | 0.487 | 0.043 | 0.930 | 175 | Sucrose parallel |
| **Fixed** | **Combined (11)** | **0.000** | **0.292** | **0.129** | **0.456** | | |
| **Random** | **Combined (11)** | **0.001** | **0.295** | **0.129** | **0.460** | | |

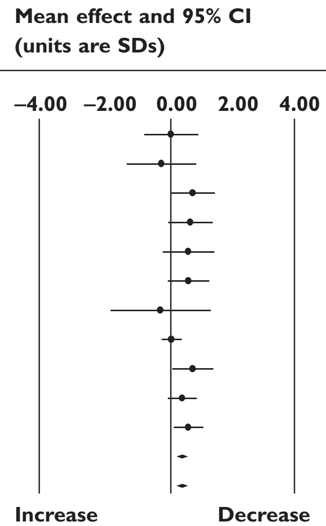


**Figure 3** Meta-analysis of studies of weight loss with sweetener (excluding outcomes with weight gain on sucrose regime). CI, confidence intervals; SD, standardised difference.

| | Study authors | Significance of effect | Effect size (SD) | Confidence limits (95%) of effect | | Study duration (weeks) | Type of control |
|---|---|---|---|---|---|---|---|
| | | *P*-Value | | Lower | Upper | | |
| | Reid & Hammersley, 1998 | 1.000 | 0.000 | −0.793 | 0.793 | 1 | Sucrose parallel |
| | Tordoff & Alleva, 1990 | 0.564 | −0.265 | −1.269 | 0.740 | 3 | Other |
| | Tordoff & Alleva, 1990 | 0.050 | 0.612 | −0.028 | 1.252 | 3 | Other |
| | Raben *et al*., 2002 | 0.087 | 0.545 | −0.109 | 1.198 | 10 | Base |
| | Gatenby *et al*., 1997 | 0.175 | 0.487 | −0.260 | 1.234 | 10 | Sucrose parallel |
| | Kanders *et al*., 1988 | 0.102 | 0.490 | −0.122 | 1.102 | 12 | Sucrose parallel |
| | Kanders *et al*., 1988 | 0.623 | −0.292 | −1.721 | 1.137 | 12 | Sucrose parallel |
| | Blackburn *et al*., 1997 | 0.919 | 0.016 | −0.294 | 0.325 | 19 | Sucrose parallel |
| **Fixed** | **Combined (8)** | **0.048** | **0.206** | **0.001** | **0.411** | | |
| **Random** | **Combined (8)** | **0.050** | **0.221** | **0.000** | **0.443** | | |

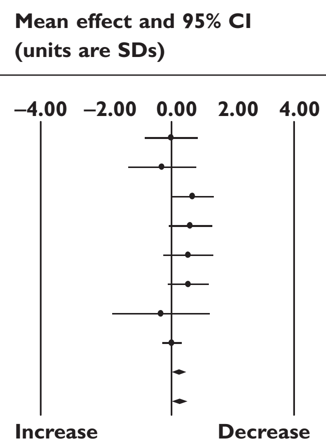


**Figure 4** Meta-analysis of studies of weight loss (intervention period only, excluding studies with weight gain on sucrose regime). CI, confidence intervals; SD, standardised difference.

**Table 4** Summary of meta-analysis of weight loss: effect size (as SD) by type of study

| Studies (number of study outcomes) | *P*-value | Effect (SD) | 95% confidence limits | |
|---|---|---|---|---|
| | | | Lower | Upper |
| All studies of weight loss (20) | 0.0000 | 0.385 | 0.242 | 0.528 |
| Excluding those with a weight-gaining control (11) | 0.001 | 0.295 | 0.129 | 0.460 |
| Excluding weight-gaining controls and follow-up data (8) | 0.050 | 0.221 | 0.000 | 0.443 |

SD, standardised difference.

weighted average study length was 12 weeks, this gives an estimated rate of weight loss of around 0.2 kg/week for a 75 kg adult.

### Weight maintenance

The two weight loss studies followed participants up for 1 year (Kanders *et al.* 1990) and 3 years (Blackburn *et al.* 1997) after the initial weight loss phase of the study. In the Kanders *et al.* study, weight maintenance was better in men who consumed more aspartame products over the follow-up period but there was no difference for women. The Blackburn *et al.* study found that weight regain was significantly less in those consuming aspartame-sweetened products than in those who were not. After 3 years, those who consumed aspartame products had maintained a weight loss of 5.1 kg compared with those in the no-aspartame group who had regained all their previous weight loss.

## Conclusions

The meta-analyses demonstrate that using foods and drinks sweetened with aspartame instead of sucrose results in a significant reduction in both energy intakes and bodyweight. The meta-analyses both of energy intake and of weight loss produced an estimated rate of weight loss of about 0.2 kg/week. This close agreement between the figure calculated from reductions in energy intake and actual measures of weight loss gives confidence that this is a true effect. The two meta-analyses used different sets of studies with widely differing designs and controls. Although this makes comparisons between them difficult, it suggests that the final figure of around 0.2 kg/week is robust and is applicable to the variety of ways aspartame-containing foods are used by consumers. This is a low but meaningful rate of weight loss and, on a population basis, more than sufficient to counteract the current average rate of weight gain of around 0.007 kg/week (NHS Health and Social Care Information Centre 2005). On an individual basis, it provides a useful adjunct to other weight loss regimes.

### Unconscious compensation

An estimated compensation rate of around one-third of energy substituted was calculated from the studies which provided sufficient information. However, basing the calculations only on studies which used soft drinks as the substitution vehicle gave a lower figure of about half this, *i.e.* around 15%. This is reasonable as it is likely that energy obtained from liquids is less satiating than that obtained from foods and so the body is less likely to adjust for the energy contained in a sucrose-containing drink than it would if the same amount of energy was provided in a solid food. Nevertheless, these compensation values are derived from short-term studies. More data are needed over the longer term to determine whether a tolerance to the effects is acquired.

### Conscious adjustment

In addition to an unconscious compensatory effect, the effects of the conscious adjustments and trade-offs that people consuming low-calorie foods make also need to be considered. Most of the studies included in the meta-analysis were blind and people did not know whether they were consuming the sugar or the aspartame-containing version. Therefore, these studies are not able to address this question.

Nevertheless, one study was not blind (Gatenby *et al.* 1997) and two studies included an unblind comparison (Mattes 1990; Lavin *et al.* 1997). In the Gatenby *et al.* study, subjects consuming the low-sugar versions had a non-significantly lower energy intake than those consuming the normal versions; however, some subjects increased their energy intake suggesting that there was an element of adjustment. In the Mattes study, both groups increased their energy intakes (non-significantly) compared with the sucrose controls but those who were aware they had consumed a low-calorie cereal did so more than those who were unaware. In the Lavin *et al.* study, both informed and uninformed groups compensated for the low-calorie drink (Lavin *et al.* 1997).

During the follow-up period of the Blackburn *et al.* trial, subjects were encouraged to continue using or not using aspartame-sweetened products according to what they had been doing during the intervention period. Over the next 3 years, those who used the aspartame-sweetened foods regained significantly less weight than those who did not (Blackburn *et al.* 1997).

Therefore, although the effect of conscious adjustment might mitigate against the expected reduction in energy intakes with casual aspartame use, it is likely to be less important for people determinedly trying to control their weight.

### Effectiveness of aspartame for weight loss

This review has shown that using foods and drinks sweetened with aspartame instead of those sweetened with sucrose is an effective way to maintain and lose weight without losing the palatability of the diet. The decrease in energy intakes and the rate of weight loss that can reasonably be achieved is low but meaningful. Some compensation for the substituted energy does occur but this is only about one-third of the energy replaced and is probably less when using soft drinks sweetened with aspartame. Nevertheless, these compensation values are derived from short-term studies. More data are needed over the longer term to determine whether a tolerance to the effects is acquired.

To achieve the average rate of weight loss seen in these studies of 0.2 kg/week will require around a 220-kcal deficit (0.93 MJ) per day using an energy value for obese tissue of 7500 kcal/kg. Assuming the higher rate of compensation (32%), this would require the substitution of around 330 kcal/day (1.4 MJ/day) from sucrose with aspartame (which is equivalent to around 88 g of sucrose). Using the lower estimated rate of compensation for soft drinks alone (15.5%) would require the substitution of about 260 kcal/day (1.1 MJ/day) from sucrose with aspartame. This is equivalent to 70 g of sucrose or about two cans of soft drinks every day.

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