Effects of sugar intake on body weight: a review

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Summary

Weight reduction programmes are mainly focused on reducing intake of fat and sugar. In this review we have evaluated whether the replacement of dietary (added) sugar by low-energy sweeteners or complex carbohydrates contributes to weight reduction. In two experimental studies, no short-term differences in weight loss were observed after use of aspartame as compared to sugar in obese subjects following a controlled energy-restricted diet. However, consumption of aspartame was associated with improved weight maintenance after a year. In two short-term studies in which energy intake was not restricted, substitution of sucrose by artificial sweeteners, investigated mostly in beverages, resulted in lower energy intake and lower body weight. Similarly, two short-term studies, comparing the effect of sucrose and starch on weight loss in obese subjects did not find differences when the total energy intake was equal and reduced. An *ad libitum* diet with complex carbohydrates resulted in lower energy intake compared to high-sugar diets. In two out of three studies, this was reflected in lower body weight in subjects consuming the complex carbohydrate diet. In conclusion, a limited number of relatively short-term studies suggest that replacing (added) sugar by low-energy sweeteners or by complex carbohydrates in an *ad libitum* diet might result in lower energy intake and reduced body weight. In the long term, this might be beneficial for weight maintenance. However, the number of studies is small and overall conclusions, in particular for the long term, cannot be drawn.

Keywords: Body weight, carbohydrates, sugar.

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Introduction

The prevalence of obesity is increasing around the world and it is a significant public health problem in many countries (1). An accurate energy balance (energy intake equals energy expenditure) is essential to maintain a stable body weight. In weight reduction programmes, dietary recommendations have been mainly focused on reducing intake of fat and sugar. In this review, we will not discuss fat, but carbohydrate intake. It is not quite clear whether the replacement of (added) sugar (meaning all simple carbohydrates [SCHOs]) by low-energy sweeteners or by complex carbohydrates (CCHOs), introduced as a tool to lower energy intake, truly contributes to weight reduction.

Replacing sugar by low-energy sweeteners may affect subjects' energy balance. Theoretically, energy intake will be lowered, while sweetness remains. However, the energy content of carbohydrates, fat and proteins, may have an impact on appetite and satiety as well (2). Therefore, consumption of products with sweeteners may lead to the adaptation of eating habits that compensate for the reduced energy intake. So, it may be possible that in the end the energy intake does not change when low-energy sweeteners are used.

In this review, published data from Medline (National Library of Medicine, Bethesda, MD), dated from 1980 onwards, on the role of sugars, CCHOs and sweeteners in human body-weight maintenance are evaluated [search words: simple or complex carbohydrate, sugar or sucrose, body weight, BMI (body mass index), sweeteners, obesity, energy intake and starch]. Only articles written in English were included, with a limitation up to 35 publications.

Studies were categorized into investigations reporting effects of dietary sugar relative to low-energy sweeteners, CCHOs and fat, on body weight. The regulation of food intake with respect to appetite, satiety and energy intake as well as adaptation of eating habits is briefly discussed.

Sugar vs. low-energy sweeteners

Few studies, which are summarized in Table 1, have investigated the effects of sugar replacement by sweeteners on body weight. Kanders *et al.* studied 59 obese men and women following an energy-restricted diet (4.2 MJ d^{-1} for women and 5 MJ d^{-1} for men) during a 12-week weight loss programme with 1-year follow-up (3,4). Subjects were either required to use aspartame-sweetened products or prohibited from using aspartame-sweetened products. Women who used aspartame-sweetened products lost more weight than non-users (7.5 kg vs. 5.8 kg), although differences were not statistically significant. The weight loss seen in the experimental group, after the active weight loss phase, compared to the control group might indicate that compliance of reduced energy intake was facilitated for subjects allowed to use low-energy sweetened products.

In a later study by the same group of investigators with obese women only, 163 subjects received an energy-restricted diet (4.2 MJ d^{-1}) during a 19-week weight loss programme (5). The women were again assigned to either consume or abstain from aspartame-containing products. After 19 weeks, the aspartame intake increased in the aspartame group and decreased in the non-aspartame group. Energy intake did not differ between the aspartame and non-aspartame groups. In both groups, women lost about 10% (9.9 kg) of body weight in the active weight loss phase, which was not different between the groups. In women who used the aspartame-sweetened products, intake of aspartame was positively correlated with loss of body weight during active weight loss. After 1-year weight maintenance, women who used aspartame-sweetened foods and beverages besides the 6.2 MJ weight maintenance diet regained significantly less weight (2.6 kg) than the non-aspartame users (5.4 kg) ($P < 0.05$). After the 2-year follow-up, the aspartame users still had a mean weight loss of 5.1 kg, whereas the non-aspartame users had regained all their weight lost. Both studies suggest that, although no short-term effects of aspartame consumption on body weight could be demonstrated, this high-intensity sweetener may be useful to maintain a reduced body weight during a weight control programme in the long term (3–5). Compliance to a weight maintenance programme seems to be facilitated with the use of low-energy sweeteners.

Because of the growing intake of soft drinks in our diet and the accompanying rise in obesity especially seen in children (6), the question arises whether there is a causal relationship. Recently, this discussion got a lot of attention and in the USA, can machines were even removed from school buildings. The evidence comes from different studies. In a 10-week supplementation study, subjects (on average 35 years) were supplemented with sucrose [3.4 MJ; 152 g sucrose per day = 28 energy percent (en%)] or artificial sweeteners (1.1 MJ; 0 g sucrose per day; aspartame, acesulfame K, cyclamate and saccharine), mostly as beverages in a further *ad libitum* diet (7). After 10 weeks, a decrease in body weight was seen in those consuming the artificially sweetened supplements (1 kg), in contrast to the increase in those supplemented with sucrose (1.6 kg) ($P < 0.001$). The main explanation for this difference in body weight was found to be the difference in energy intake coming from experimental fluids. DiMeglio and Mattes have already reported that compensation of energy intake is less accurate with energy intake from liquids vs. solid foods (8). Carbohydrate intake from liquids therefore promotes a positive energy balance, whereas carbohydrate intake from solid foods will be compensated for (8).

In a cross-over study, Tordoff and Alleva compared 3 weeks consumption of 1150 g soda sweetened with aspartame (3 kcal = 12.6 kJ) per day with 1150 g high-fructose corn syrup (530 kcal = 2.2 MJ) per day, and with no soda (control) in 30 men and women with a healthy body weight (9). After 3 weeks consumption of high-fructose corn syrup, body weight was significantly increased as compared to consumption of aspartame-sweetened soda and no soda. In both groups consuming experimental drinks, energy intake from the diet was lowered as compared to control [7.5 MJ for diet with the aspartame-sweetened soda; 7.3 MJ for diet with the high-fructose corn syrup (excluding 2.2 MJ from the soda); 8.5 MJ per day for the control diet]. When energy content of the high-fructose corn syrup was included, energy intake in this group was higher than that in the group using the aspartame-sweetened soda and the control group. The only difference in energy intake between the diets with the experimental drinks was the amount of energy from the high-fructose corn syrup (2.2 MJ), which may explain the difference in body weight between these groups. In both treatment groups, sugar intake from the diet was reduced as compared to the control group, probably because commonly used energy-containing drinks were replaced by experimental drinks (9). From this short-term study, it may be concluded that reducing total sugar intake by replacing consumption of large volumes of high-fructose-containing soda by aspartame-sweetened drinks may be favourable for body-weight control. This would only be favourable when there is no compensation for the reduced energy intake from other food products.

In a long-term observational study (19 months), Ludwig and colleagues reported a positive relation between intake of sugar-sweetened drinks and prevalence of childhood obesity (6). The beverage intake (of 57% of the participating

Table 1 Experimental studies investigating effects of sugar relative to sweeteners in relation to body weight

Reference	Subjects	Period	Design	Experimental groups	Products	Results (Body weight)
Kanders *et al.* 1988 (3)	59 obese subjects (13 ♂ and 46 ♀)	12 weeks	Parallel	I: Energy-restricted diet: 4.2 MJ for ♀ and 5 MJ for ♂ + aspartame-containing products II: Energy-restricted diet: 4.2 MJ for ♀ and 5 MJ for ♂ + no aspartame-containing products Both combined with an exercise programme	I: Milk products, drinks, sweeteners	I: ↓ 7.4 kg (7.5%) ♀ and 10.4 kg (9.5%) ♂ II: ↓ 5.8 kg (5.8%) ♀ and 12.2 kg (11.7%) ♂ No difference between the groups
Blackburn *et al.* 1997 (5)	163 obese women	19 weeks; 1-year weight maintenance; 2-year follow-up	Parallel	I: Energy-restricted diet (4.2 MJ) + aspartame-containing products II: Energy-restricted diet (4.2 MJ) + no aspartame-containing products Both combined with an exercise programme	I: Milk products, drinks, sweeteners II: Sugar, honey	I: ↓ 9.9 kg ($P < 0.0001$) II: ↓ 9.8 kg ($P < 0.0001$) No difference between the groups; better weight maintenance for the aspartame group ($P < 0.05$), regain 2.6 kg vs. 5.4 kg
Raben *et al.* 2002 (7)	41 obese subjects (6 ♂ and 35 ♀)	10 weeks	Parallel	I: *Ad libitum* diet with artificial sweeteners-containing products (1.1 MJ) II: *Ad libitum* diet with sucrose-containing products (3.4 MJ)	I + II: Drinks and solid foods (yoghurt, marmalade, ice cream, stewed fruits)	I: ↓ 1 kg II: ↑ 1.6 kg Significant difference between the groups ($P < 0.001$)
Tordoff & Alleva 1990 (9)	30 healthy-weight subjects (21 ♂ and 9 ♀)	3 × 3 weeks	Cross-over	I: 1150 g aspartame-sweetened soda (12.6 kJ) II: 1150 g high-fructose corn syrup (2.2 MJ) III: No aspartame-sweetened soda (control)	I: Soda II: Syrup	I: ↓ 0.11 kg ♀ 0.35 kg ♂ II: ↑ 0.61 kg ♀ 0.64 kg ♂ III: ↓ 0.36 kg ♀ 0.12 kg ♂ Significant difference between groups ($P < 0.01$)