

## Increased satiety after intake of a chocolate milk drink compared with a carbonated beverage, but no difference in subsequent *ad libitum* lunch intake

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The rising rate of obesity has been blamed on increased consumption of sugar-sweetened soft drinks, such as carbonated sodas, which fail to satisfy hunger. The objective of the present study was to compare the effect on appetite and energy intake of a sugar-sweetened beverage (cola) and a chocolate milk drink, matched for energy content and volume. It was hypothesised that chocolate milk may be more satiating because of its protein content. Twenty-two healthy young men (age 23 (SD 1.8) years) of normal weight (BMI 22.2 (SD 1.5) kg/m<sup>2</sup>) were recruited to the randomised cross-over study. Visual analogue scales were used to record subjective appetite ratings every 30 min on each of two test days. A drink of 500 ml cola or chocolate milk (900 kJ) was ingested 30 min before an *ad libitum* lunch. Satiety and fullness were significantly greater ( $P=0.0007$ ,  $P=0.0004$ , respectively) 30 min after chocolate milk than after cola. Ratings of prospective consumption and hunger were significantly greater after cola than after chocolate milk, both immediately after preload intake ( $P=0.008$ ,  $P=0.01$ , respectively) and 30 min afterwards ( $P=0.004$ ,  $P=0.01$ , respectively). There was no significant difference ( $P=0.42$ ) in *ad libitum* lunch intake after ingestion of chocolate milk (3145 (SD 1268) kJ) compared with cola (3286 (SD 1346) kJ). The results support the hypothesis that sweetened soft drinks are different from milk products in their impact on short-term hunger and satiety, although differences in subjective appetite scores were not translated into differences in energy intake.

**Satiety: Hunger: Appetite: Energy intake: Soft drinks: Preloads**

High consumption of sugar-sweetened beverages is associated with weight gain, obesity and increased risk of type 2 diabetes in both adults and children (Ludwig *et al.* 2001; Bray *et al.* 2004; Schulze *et al.* 2004). The energy content of carbonated sodas, in particular, does not appear to be compensated for during meals (Ludwig *et al.* 2001). Some studies have suggested that liquids differ from solid foods in their effects on hunger, satiety and energy compensation (Almiron-Roig *et al.* 2003). Soft drinks have thus been described as thirst-quenching liquids that somehow bypass the satiety mechanisms regulating food consumption (Almiron-Roig & Drewnowski, 2003). However, the evidence is inconclusive. Other studies have suggested that energy compensation after an energy-containing beverage is instead dependent on the volume of the beverage and the timing of consumption before a meal (Almiron-Roig *et al.* 2004). It has been argued, also, that some beverages have more of an effect on satiety than others. Hence sugar energy consumed in the form of fruit juice or milk may be more satiating compared with carbonated sugar-sweetened beverages (Rolls & Barnett, 2000; Almiron-Roig & Drewnowski, 2003).

The energy densities of low-fat (1%) milk, orange juice and regular cola are almost identical (about 1.8 kJ/g); thus if these

beverages differentially affect appetite and satiety then factors other than energy density must be involved. The present study aimed to compare the effect on appetite and energy intake of a sugar-sweetened beverage (cola) and a chocolate milk drink (containing protein and fat in addition to sugar), matched for energy content and volume. Studies with solid foods have indicated a satiety hierarchy for the macronutrients: protein > carbohydrate > fat (Rolls *et al.* 1988; Hill & Blundell, 1990; Hall *et al.* 2003; Weigle *et al.* 2005), but there is less evidence to support that this hierarchy holds true in liquids (Stubbs & Whybrow, 2003). In one study, consumption of a liquid meal replacement composed of sugar, fat and protein led to increased satiety than after an isoenergetic beverage containing only sugar (St-Onge *et al.* 2004). Furthermore, hunger and desire to eat were less after a protein fruit juice beverage than after juices comprised of fat or carbohydrate (Westerterp-Plantenga & Verwegen, 1999), although there was no difference in subsequent energy intake at lunch. However, another study found no difference between 1% low-fat milk, cola and juice in terms of hunger and satiety ratings or energy intake at the subsequent lunch (Almiron-Roig & Drewnowski, 2003), and no differences in appetite scores between beverages high in protein, carbohydrate or fat were reported in an earlier study (de Graaf *et al.* 1992).

**Abbreviations:** GI, glycaemic index; VAS, visual analogue scale.

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In the present cross-over randomised study of the effect on short-term appetite profile and subsequent energy intake of cola compared with chocolate milk, a preload-meal interval of 30 min was used. This interval has previously been associated with a compensatory effect on energy intake (Westerterp-Plantenga & Verwegen, 1999). An *ad libitum* lunch, identical at each visit, was provided 30 min after consumption of the liquid preload. The hypothesis was that the chocolate milk would suppress appetite more than the cola because of its protein content.

## Subjects and methods

### Subjects

Male subjects were recruited for the study at the Panum Institute and The Royal Veterinary and Agricultural University (Copenhagen, Denmark) by means of advertisements. The inclusion criteria were: age 20–40 years, of normal weight (BMI range 18.5–25 kg/m<sup>2</sup>), non-smokers, not elite sportsmen, no previous history of diabetes, overweight, hypertension or liver disease, no daily use of medicine or excessive alcohol use. During recruitment, subjects were informed of the meals and preload beverages to be provided and asked to state any dislikes (none were noted). Twenty-two young men (age 23 (SD 1.8) years) of normal weight (BMI 22.2 (SD 1.5) kg/m<sup>2</sup>) were enrolled in the study and there was no drop-out. The study was approved by the Municipal Ethical Committee of Copenhagen and Frederiksberg and was in accordance with the latest version of the Helsinki Declaration. All subjects gave their written consent after the experimental procedure had been explained to them verbally and in writing.

### Design

The study had a cross-over randomised design. Subjects were randomly assigned to whether the preload on the first visit was cola or chocolate milk (half in each group). On each of two test days, with at least 1 week between them, subjects reported at the Department of Human Nutrition in a fasted state. Strenuous physical activity was not permitted the day before each visit and it was requested that the evening meal be no later than 21.00 hours; water was permitted (up to 300 ml and 200 ml on the evening before and the morning of the study, respectively). On arrival at 08.00 hours, subjects were weighed and their height was measured. Subjects were then provided with breakfast, which consisted of porridge oats (Quaker Oats Ltd, c/o Consiva Foods A/S, Herlev, Denmark) with semi-skimmed milk, orange juice and either caffeine-free coffee, tea or water. An identical breakfast was provided on the second visit. Visual analogue scales (VAS) were used to record subjective appetite ratings every 30 min from 08.30 hours ( $t = 0$ ), just before the breakfast meal, until 30 min after lunch ( $t = 240$  min). The preload beverage of 500 ml cola or chocolate milk (matched for energy content at 900 kJ) was given at 11.30 hours ( $t = 180$  min). VAS were also recorded just after intake of the beverage ( $t = 190$  min) and again just before the *ad libitum* lunch ( $t = 210$  min), which was provided at 12.00 hours. Ratings of hunger, satiety, fullness, prospective food consumption, thirst, desire for something salty, sweet or fatty, or some meat or fish were

recorded on a 100 mm scale anchored with 'not at all' and 'extremely'. How comfortable a subject felt was also recorded. The time interval of 30 min between preload and lunch was chosen based on a previous study, which showed that this interval had an effect with a 1.3 MJ preload (a milk shake compared with water or no preload) and that this effect was not due to volume (Westerterp-Plantenga & Verwegen, 1999). Information about the appearance and palatability of the meals and preload beverages was also recorded within 10 min of ingestion.

Power analysis indicated that a sample of eighteen subjects should be sufficient in a cross-over study to detect a difference of 5 mm on mean 4.5 h VAS ratings, with a power of 80% (Flint *et al.* 2000). With twenty-two subjects, statistical significance of 0.05 and a power of 80%, a difference in 660 kJ energy intake should be detectable at lunch 30 min after preload (Rolls *et al.* 1991), with the reservation that this power analysis was based on comparison between a carbohydrate preload compared with no preload.

### Test meals and beverages

The breakfast had an energy content of 2.5 MJ. Lunch, which was provided separately to each subject and which they could consume *ad libitum* until pleasantly full, was a pasta salad consisting of a homogeneous mix of pasta, ham, carrots, peas and dressing, prepared by the kitchen staff in the Department. The amount of food ingested at lunch was measured using a digital scale. Subjects had 20 min to eat both breakfast and lunch and the macronutrient composition of the meals was 15% energy from protein, 30% from fat and 55% from carbohydrate. Intake of *ad libitum* water was allowed with lunch on the first visit and the amount for each subject was recorded; the same amount of water was provided on the second visit. The beverages consisted of Coca Cola (Coca Cola Nordic Services A/S, Hellerup, Denmark) and Matilde skimmed-milk chocolate milk (Arla Foods, Viby J, Denmark), both served cold. The energy content and nutrient composition of each preload beverage are shown in Table 1. The chocolate milk was presented with a separate glass of water so that the total energy content and volume was identical to that of the cola (chocolate milk of matching energy density was not available). Subjects were instructed to drink equally from the chocolate milk and the water glasses. The beverages in total had the same energy density (1.6 kJ/g) and supplied 900 kJ energy each. The cola contained energy only in the form of carbohydrate, whereas the chocolate milk also contained protein and fat. The study was designed so that

**Table 1.** Energy and macronutrient composition of the preload beverages

	Chocolate milk	Cola
Volume (ml)	500*	500
Energy (kJ)	900	900
Carbohydrate (g)	36	53
Protein (g)	12.6	0
Fat (g)	1.8	0
Energy density (kJ/g)	1.6	1.6

\* Provided as 346 ml chocolate milk and 154 ml water in a separate glass.

there was a maximum of five subjects at the Department on a given test day, and subjects were kept apart, though in the same room, throughout the morning.

### Statistical analyses

The postprandial response curves were compared by ANOVA using mixed linear models with repeated measures. *Post hoc* ANOVA was used to test differences between the two groups (chocolate milk and cola) at individual time points; the factors were treatment, order and treatment  $\times$  order. The mixed procedure in the Statistical Analysis System software package (version 9.1; SAS Institute, Cary, NC, USA) was used to test differences in appetite factors and energy intake. A significance level of  $P < 0.05$  was used for all statistical tests (two-sided).

## Results

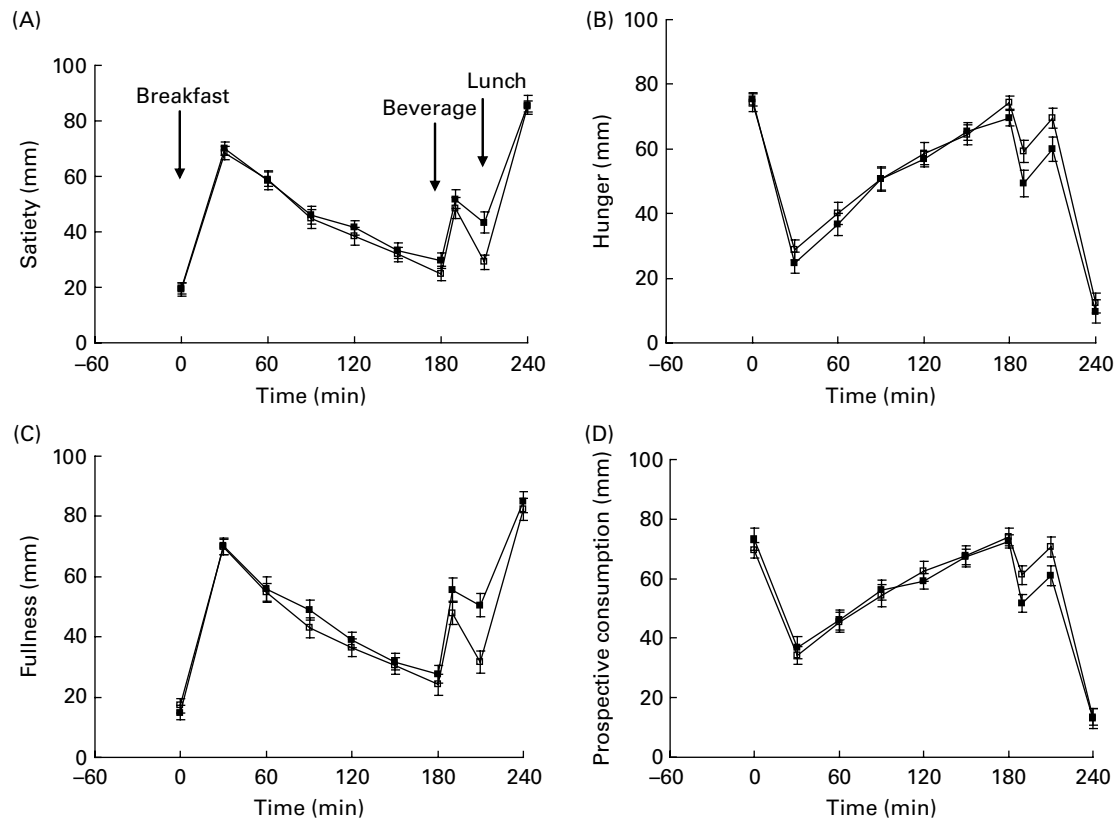
### Evaluation of test meals and beverages

There were no differences in subjective evaluation of the two preload beverages; both were equally well liked (in terms of appearance, aroma, taste and palatability) by the subjects. Overall palatability was 23 (SD 15) and 30 (SD 23) mm for chocolate and cola, respectively (0 = high palatability,

100 mm = low). Scores for the other parameters were similar. Similarly, scores for appearance and taste, etc, of the breakfast and lunch meals did not differ.

### Subjective appetite ratings

Satiety and fullness, rated by subjective VAS scores, were significantly greater ( $F(1, 20) = 16.18$ ,  $P = 0.0007$  and  $F(1, 20) = 18.20$ ,  $P = 0.0004$ , respectively) 30 min after the chocolate milk (just before lunch,  $t = 210$  min) than after the cola drink (Fig. 1). Ratings of prospective consumption and hunger were significantly greater after cola than after chocolate milk, both just after intake of the beverage at  $t = 190$  min ( $F(1, 20) = 8.69$ ,  $P = 0.008$ , and  $F(1, 20) = 7.89$ ,  $P = 0.01$ , respectively), and also just before lunch at  $t = 210$  min ( $F(1, 20) = 10.82$ ,  $P = 0.004$ , and  $F(1, 20) = 7.96$ ,  $P = 0.01$ , respectively). The preference for savoury or high-protein foods was significantly lower after chocolate milk than after cola at  $t = 210$  min (data not shown) (salty food:  $F(1, 20) = 9.24$ ,  $P = 0.007$ ; fatty food:  $F(1, 20) = 14.79$ ,  $P = 0.001$ ; meat or fish:  $F(1, 20) = 7.96$ ,  $P = 0.01$ ). No significant differences were observed in subjective appetite ratings at other time points of the study ( $P > 0.05$ ) and no differences in thirst, desire to eat something sweet or wellbeing were observed throughout the study.



**Fig. 1.** Subjective appetite sensations in twenty-two normal-weight men after intake of a preload beverage, chocolate milk (■) or cola (□), 30 min before an *ad libitum* lunch. A visual analogue scale rating equal to 100 mm corresponds to (A) 'I cannot eat another bite' (satiety); (B) 'I have never been hungrier' (hunger); (C) 'I am totally full' (fullness); (D) 'I can eat a lot' (prospective food consumption). Data are mean values, with their standard errors represented by vertical bars. By ANOVA, there was a treatment effect just after preload beverage ( $t = 190$  min) for hunger ( $P = 0.02$ ) and prospective consumption ( $P = 0.005$ ). There was a treatment effect immediately before *ad libitum* lunch intake ( $t = 210$  min) for satiety ( $P = 0.0007$ ), hunger ( $P = 0.01$ ), fullness ( $P = 0.0004$ ) and prospective consumption ( $P = 0.004$ ). There was no effect of time or treatment  $\times$  time ( $P > 0.05$ ) for all parameters.

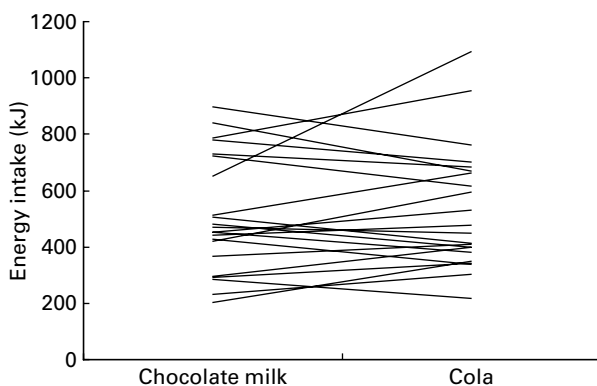
### *Ad libitum* energy intake

Despite significant differences in subjective appetite ratings between preload beverages, these were not translated into differences in energy intake at lunch. Although there was overall a 4% greater intake of *ad libitum* lunch after ingestion of cola (3286 (SD 1346) kJ) compared with chocolate milk (3145 (SD 1268) kJ), this difference was not significant ( $F(1, 20) = 0.68$ ,  $P=0.42$ ; Fig. 2). Results were variable, with eleven subjects ingesting more after the chocolate milk and eleven ingesting more after cola; standard deviations were thus very high. Statistical analysis showed that there was no effect of treatment order (chocolate milk or cola on the first visit day) on any appetite parameter or energy intake at lunch.

### Discussion

The increased short-term satiety observed after the consumption of chocolate milk compared with cola was in contrast to a previous study, which found no differences in subjective appetite profiles between low-fat (1%) milk, cola and orange juice (Almiron-Roig & Drewnowski, 2003). In that study, subjects were given a slice of toast with the beverage, which provided 418 kJ out of the total 1454 kJ, and this could have masked the effect on appetite of beverage alone. Beverages in both studies were matched for energy density and energy content, but differed in their nutrient composition and sensory characteristics. Nutritional and sensorial differences between beverages could thus account for possible differential effects on satiety.

The protein content of the chocolate milk provides one explanation for the increased satiety we observed compared with sugar-rich cola, and supports the concept of a satiety hierarchy for the macronutrients: protein > carbohydrate > fat (Rolls *et al.* 1988; Hill & Blundell, 1990; Hall *et al.* 2003; Weigle *et al.* 2005). In a recent study, greater ratings of satiety were observed after consumption of a liquid formula composed of sugar, fat and protein than after an isoenergetic beverage containing only sugar (St-Onge *et al.* 2004), and hunger and desire to eat were reduced after a protein fruit juice compared with after juices comprised of fat or carbohydrate (Westerterp-Plantenga & Verwegen, 1999). In contrast, in another study no differences in appetite profiles were reported



**Fig. 2.** Spontaneous energy intake at an *ad libitum* lunch 30 min after consumption of a preload beverage, chocolate milk or cola, in twenty-two normal-weight men. Mean energy intakes at lunch were 3145 (SD 1268) kJ after the chocolate milk and 3286 (SD 1346) kJ after cola. There was no significant difference in energy intake at lunch ( $P=0.42$ ).

after beverages high in protein, carbohydrate or fat (de Graaf *et al.* 1992), provided after an overnight fast. Differences in the timing of preload and the interval between preload and test meal could explain differences between studies (de Graaf *et al.* 1992; Almiron-Roig *et al.* 2004). Also, factors other than protein content could be involved.

One such factor could be glycaemic index (GI). Cola has a relatively higher GI than chocolate milk (about 58 v. 34) (Foster-Powell *et al.* 2002) and some studies suggest that foods with a low GI are more satiating than foods with a high GI (Pawlak *et al.* 2002). Another factor is viscosity. A cross-over study in which subjects were given shakes matched for macronutrient content and energy density but which varied in viscosity (by addition of <0.1 g methylcellulose) indicated that the thicker shake significantly reduced hunger compared with a thin shake (Mattes & Rothacker, 2001). Differences in sensory properties such as viscosity could also partly explain the greater prospective consumption and hunger ratings observed immediately after consumption of the cola in the present study (whilst satiety and fullness were the same for both beverages). The effect on appetite of the chocolate milk could also have been brought about by its content of cocoa powder, which could have elicited a raised insulin response. Chocolate products have been shown to elicit greater postprandial insulin secretion than products with alternate flavouring (Brand-Miller *et al.* 2003). Chocolate milk elicited 45% greater insulinaemia than strawberry flavoured milk, despite no difference in GI or glucose area under the curve. It was speculated that specific insulinogenic compounds in cocoa powder (as yet unknown) may directly stimulate  $\beta$ -cell insulin secretion, and it is interesting to note that high insulin responses have been associated with short-term appetite regulation and increased satiety in healthy subjects (Flint *et al.* 2005). Moreover, milk products in general have been shown to be insulinotropic (Ostman *et al.* 2001). Some or all of the above factors could partly explain the satiating effect of chocolate milk in the present study.

Despite the fact that chocolate milk and cola differed in their effects on subjective appetite responses, there was no subsequent difference in energy intake at the *ad libitum* lunch. Similarly, increased short-term satiety after a protein fruit juice compared with juices comprised of fat or carbohydrate was not matched by reduced energy intake at lunch (Westerterp-Plantenga & Verwegen, 1999). Studies which have demonstrated energy compensation after liquid preloads have used a short time interval between preload and test meal of up to 30 min (Kissileff *et al.* 1984; Rolls *et al.* 1990, 1991; Spiegel *et al.* 1997; Himaya & Louis-Sylvestre, 1998), and volume also seems to be important (Rolls *et al.* 1998, 1999). Energy intake 30 min after a 1.3 MJ milk shake was significantly lower than after a water control or no preload, and this was assumed not to be due to volume (Westerterp-Plantenga & Verwegen, 1999). The preloads in the present study had a lower energy content of 900 kJ, which could explain why we observed no energy compensation at lunch. Differences in sensory properties such as viscosity could also have had an effect. In addition, the present study was powered primarily to detect differences in VAS. It is possible that a difference in energy intake might have been detected with greater power. However, it cannot be ruled out that energy-containing beverages in general do not promote energy compensation at the next meal.

In the present study, a desire for salty or fatty food, or meat or fish, was significantly greater after cola than after chocolate milk. It is possible that had a buffet-style lunch been provided with more choice as to food components, then a difference in energy intake between the two beverages might have been observed. Provision of *ad libitum* meals in small studies such as this could be an inherent difficulty of the study design; changes in intake might in real life be more readily observed over time, in the subject's home setting. The fact that up to five subjects also sat in the same room at each visit, albeit apart from each other, could also have affected their eating behaviour.

In summary, ingestion of chocolate milk increased subjective ratings of satiety and fullness compared with cola and decreased hunger and prospective consumption, whereas *ad libitum* energy intake was unaltered. The present study has been conducted in the light of controversy about the role of sweetened beverages and their failure to satisfy hunger. Long-term interventions have found that consumption of sugar-sweetened sodas leads to increased energy intake and weight gain in both adults and children (Ludwig *et al.* 2001; Raben *et al.* 2002; Bray *et al.* 2004; Schulze *et al.* 2004). The present study involved a small homogeneous group of subjects in a simple cross-over study. Further long-term studies are required to investigate how different beverages affect weight and appetite factors and to determine if and how differences in appetite ratings can be converted into that which is ultimately required, a difference in energy intake.

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