Skim milk compared with a fruit drink acutely reduces appetite and energy intake in overweight men and women

Emma R Dove, Jonathan M Hodgson, Ian B Puddey, Lawrence J Beilin, Ya P Lee, and Trevor A Mori

ABSTRACT
Background: Several studies show that proteins, including whey and casein, are more satiating than carbohydrates. It follows that skim milk would be more satiating than sugar-rich beverages. However, this has yet to be shown.

Objective: The objective was to investigate the effects of drinking skim milk in comparison with a fruit drink at breakfast on self-reported postmeal satiety and energy intake at lunch.

Design: In a randomized crossover trial, 34 overweight women (n = 21) and men (n = 13) attended 2 sessions 1 wk apart. At each session, participants consumed a fixed-energy breakfast together with either 600 mL skim milk (25 g protein, 36 g lactose, <1 g fat; 1062 kJ) or 600 mL fruit drink (<1 g protein, 63 g sugar, <1 g fat; ≈1062 kJ). Participants provided satiety ratings throughout the morning. Four hours after breakfast they consumed an ad libitum lunch, and energy intake was assessed.

Results: Participants consumed significantly less energy at lunch after consuming skim milk (mean: 2432 kJ; 95% CI: 2160, 2704 kJ) than after consuming the fruit drink (mean: 2658 kJ; 95% CI: 2386, 2930 kJ), with a mean difference of ≈8.5% (P < 0.05). In addition, self-reports of satiety were higher throughout the morning after consumption of skim milk than after consumption of the fruit drink (P < 0.05) with the differences becoming larger over the 4 h (P < 0.05).

Conclusion: Consumption of skim milk, in comparison with a fruit drink at breakfast, leads to increased perceptions of satiety and to decreased energy intake at a subsequent meal. This trial was registered with the Australian New Zealand Clinical Trials Registry at www.anzctr.org.au as ACTRN12608000510347.

INTRODUCTION
Increasing rates of obesity worldwide have been paralleled by increasing rates of consumption of sugar-sweetened beverages, including soft drinks, energy drinks, and fruit drinks (1, 2). Although liquids are generally less satiating than solids (3), there is concern that sugar-rich drinks in particular have a relatively low satiating power and that this may promote positive energy balance and weight gain (4). Evidence suggests that the nutrient composition of the diet is an important factor in controlling satiety and energy intake and that dietary protein is more satiating than carbohydrate or fat (5, 6).

Milk is high in protein and might be expected to exert a greater satiating effect than drinks composed predominantly of carbohydrate. Although studies investigating the effect of liquids supplemented with whey or casein (both dairy proteins) generally report an appetite-suppressing effect (7–10), studies using milk have failed to show a reduction in energy intake. For example, energy intakes were similar when a test meal was provided 30 min after an energy-matched preload of chocolate-flavored milk or cola (11) and 50 min after an energy-matched preload of milk or drinks sweetened with sucrose or high-fructose corn syrup (12). Similarly, energy intake at a test meal was similar between energy-matched drinks of skim milk, cola, or orange juice when the drinks were provided with the test meal (13) or as a preload 2 h and 15 min before the test meal (14).

These results might be because of the relatively small time lapse between provision of the milk preload and the subsequent test meal. Fischer et al (15) reported that the satiating effect of protein, as compared with carbohydrate, appears to be greatest when assessed over several hours. This is supported by findings that the provision of energy-matched liquid preloads containing proteins such as whey, soy, gluten, and casein resulted in decreased energy intake (by ≈10%) at a meal provided 3 h later, as compared with a preload containing glucose (9, 10). In contrast, when liquid preloads high in protein or glucose are provided <2 h before an ad libitum meal, there are generally no differences in energy intake (11, 12, 16).

It is important to test the satiating power of milk, as compared with a sugar-rich beverage, over a period of time that approximates a typical time between meals. In the Australian population, breakfast and lunch are typically 4–6 h apart. The aim of this study was to compare the effect of 2 common breakfast beverages—skim milk and fruit drink—on self-reported postmeal satiety and energy intake at lunch in overweight men and women. It was hypothesized that, in comparison with an energy-matched fruit drink, drinking skim milk with a fixed-energy breakfast would result in higher postmeal satiety and in decreased energy intake at a subsequent ad libitum lunch consumed 4 h after the breakfast.

SUBJECTS AND METHODS

Subjects
Newspaper advertisements were used to recruit overweight but otherwise healthy men and women who were interested in...
participating in a study of “the effect of drinks consumed at breakfast on appetite.” All participants were screened at the Royal Perth Hospital, Perth, Australia, to determine their eligibility for study participation. Eligibility criteria included the following: aged 25–70 y; a body mass index (BMI; in kg/m²) of 26–37; no current major illness such as cancer; nonsmoking; no diagnosed diabetes or an active psychiatric illness, including an eating disorder; consuming breakfast regularly; not currently dieting; and a stable body weight (weight change of <6% in the previous 6 mo). All participants provided written informed consent, and the study was approved by the University of Western Australia Human Research Ethics Committee.

Study design
This was a randomized, controlled crossover trial. Each participant attended 2 testing days, 1 wk apart, and was administered beverages on the same day of the week and at the same time of day. The beverages were presented in random order, but the presentation was not blinded. Visual analog scale (VAS) ratings were used to assess changes in appetite throughout each testing day. Energy intake at an ad libitum lunch was measured to assess differences in energy intake after consumption of the beverages. Participants were not aware that energy intake at the lunch meal would be assessed and were told that lunch was provided only in order to examine their subjective appetite ratings in response to the meal. Care was also taken not to reveal the study hypothesis to participants.

Participants were asked to maintain their usual diet, physical activity, and medication regimens for 2 wk before the intervention and during the 2 wk of the intervention period. To avoid a second meal effect, on the night before each visit participants consumed the same evening meal. In addition, participants did not consume alcohol or engage in vigorous physical activity for 24 h before each visit. Participants went to the Royal Perth Hospital campus for each study visit in the morning after a 12-h fast. Each participant began their test visits at the same time, and all test visits began between 0700 and 0830. Participants were asked to stay in the laboratory for this entire length of time, given 30 min in which to consume the meal. Participants were required to stay in the laboratory for this entire length of time, after which they again provided a VAS rating of their appetite. The platters were weighed before serving and weighed again when the participant had finished eating. Total energy intake was then calculated.

Participants were also permitted to consume one 250-mL cup of coffee, tea, or water 2 h after breakfast and with the lunch meal. If they selected a beverage, participants were required to consume that same beverage in the same volume and at the same time at both study visits.

Baseline measurements
At screening, height was measured with a wall-mounted stadiometer, and weight was measured with digital medical scales (model S-YB; Wedderburn, Shanghai, China) with the participant wearing light indoor clothing and no shoes. Height and weight were used to calculate BMI. Systolic and diastolic blood pressures and heart rate were measured in the supine position with an automatic blood pressure monitor (Dinamap, model 1846SX; Critikon Inc, Tampa, FL). Participants rested for 5 min, and then blood pressure and heart rate were measured 3 times within 6 min. Resting blood pressure and heart rate were determined as the average of the final 2 measurements. Blood glucose, total cholesterol, triglycerides, LDL cholesterol, and HDL cholesterol were measured from a fasting blood sample. Analyses were performed by using routine methods in the PathWest Laboratories at Royal Perth Hospital.

A study-specific questionnaire was administered to each participant to collect information regarding physical health and use of medications and alcohol and to confirm that the participant was not currently following any particular type of diet in an attempt to lose weight. Participants also completed the questionnaire version of the Eating Disorder Examination (20) to screen for eating disorders and to ascertain their level of dietary restraint. The mean (±SD) global score for the Eating Disorder Examination questionnaire was 1.8 ± 1.1, and the mean (±SD) score for dietary restraint was 1.4 ± 1.3. Comparison of these scores (as well as examination of the responses to the diagnostic items) with published community-based norms (20) indicated that no participant had an eating disorder.
Statistical analysis

Statistical analyses were performed by using SPSS 15.0 software (SPSS Inc, Chicago, IL) and SAS 8.2 software (SAS Institute, Cary, NC). Descriptive statistics are presented as means ± SDs. Results are presented as means and 95% CIs in the text or as means ± SEs (SEMs) in the figures. There was no difference in results when the order of beverage presentation was considered. Differences in (1) energy intake at lunch, (2) the 4-h postbreakfast incremental area under the curves for self-reported satiety scores, and (3) self-reported satiety at baseline and immediately postlunch were compared by using paired t tests. The baseline-adjusted, 4-h, postbreakfast, self-reported satiety scores were analyzed with random-effects models by using PROC MIXED (SAS Institute). Models included a time-by-treatment interaction term to test whether the slopes of the curves differed, that is, whether the curves were significantly nonparallel. These models were also used to determine whether the mean postbreakfast satiety scores were different. In the random-effects models, participant was treated as the random effect, accounting for correlated error structures, and treatment (skim milk or fruit drink) and treatment order were the fixed effects. Statistical significance was set at \( P < 0.05 \) (2-tailed).

RESULTS

Participants and baseline characteristics

The trial profile showing the number of participants at each stage of the study recruitment and at completion is provided in Figure 1. Thirty-four participants (13 males and 21 females) completed the study. Participant characteristics are shown in Table 2.

Energy intake at the test meal

The mean energy intake at the ad libitum test meal was 2432 kJ (95% CI: 2160, 2704 kJ) after consuming skim milk and 2658 kJ (95% CI: 2386, 2930 kJ) after consuming the fruit drink (Figure 2). The 226-kJ (95% CI: 9, 443 kJ), or \( \approx8.5\% \), difference between treatments was statistically significant (\( P = 0.04 \)).

Self-reported satiety

Before the breakfast meal (\( t = 0 \)) there was no difference between treatments in the participants’ mean VAS ratings of fullness (mean difference: 4.35 ± 29.72 mm; \( P = 0.40 \)), satisfaction (mean difference: 1.06 ± 28.85 mm; \( P = 0.83 \)), or prospective consumption (mean difference: 3.21 ± 26.18 mm; \( P = 0.48 \)). The mean satiety ratings over the 4-h postbreakfast periods were significantly different in the study treatments. The mean VAS rating for fullness, satisfaction, and prospective consumption indicated significantly greater satiety after consuming skim milk than after consuming the fruit drink (Table 3).

The mean differences from baseline in VAS satiety ratings over the 4-h postbreakfast period are presented in Figure 3. Significant time-by-treatment interactions were observed for fullness (\( P = 0.02 \)) and satisfaction (\( P = 0.001 \)), which indicated a difference in the slope of the curves (Figure 3). The time-by-treatment interaction was not significant for prospective consumption (\( P = 0.74 \)).

Figure 1. Trial profile showing the number of participants at each stage of study recruitment and at completion.

Differences in the incremental area under the curve (AUC) between treatments were also observed for VAS ratings of satiety. The AUC for the VAS rating of fullness was significantly different between study treatments [10,665 mm \( \cdot \) min (95% CI: 4571, 9451 mm \( \cdot \) min) for skim milk and 6832 mm \( \cdot \) min (95% CI: 4285, 9379 mm \( \cdot \) min) for fruit drink; \( P = 0.006 \)]. Similarly, the AUC for the VAS rating of prospective consumption was significantly different [−5584 mm \( \cdot \) min (95% CI: −7275, −3892 mm \( \cdot \) min) for skim milk and −2623 mm \( \cdot \) min (95% CI: −4445, −801 mm \( \cdot \) min) for the fruit drink; \( P = 0.005 \)]. The AUC for the VAS rating of satisfaction did not differ significantly [7708 mm \( \cdot \) min (95% CI: 5527, 9889 mm \( \cdot \) min) for skim milk and 5835 (95% CI: 3441, 8230 mm \( \cdot \) min) for fruit drink; \( P = 0.11 \)].

Correlations of self-reported satiety with energy intake

Correlation analyses indicated that VAS ratings of appetite were more consistently related to subsequent energy intake after

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean ± SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>55.1 ± 12.5</td>
<td>25–70</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.67 ± 0.10</td>
<td>1.51–1.90</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>90.2 ± 14.4</td>
<td>63.5–125.7</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>32.4 ± 3.4</td>
<td>26.5–39.0</td>
</tr>
<tr>
<td>Systolic blood pressure (mm Hg)</td>
<td>128.1 ± 15.8</td>
<td>98.0–162.5</td>
</tr>
<tr>
<td>Diastolic blood pressure (mm Hg)</td>
<td>71.8 ± 9.0</td>
<td>55.0–89.0</td>
</tr>
<tr>
<td>Plasma glucose (mmol/L)</td>
<td>5.5 ± 0.5</td>
<td>4.8–6.9</td>
</tr>
<tr>
<td>Total cholesterol (mmol/L)</td>
<td>5.2 ± 1.1</td>
<td>3.3–7.8</td>
</tr>
<tr>
<td>Triglycerides (mmol/L)</td>
<td>1.2 ± 0.5</td>
<td>0.5–2.4</td>
</tr>
<tr>
<td>LDL cholesterol (mmol/L)</td>
<td>3.2 ± 0.9</td>
<td>2.0–5.3</td>
</tr>
<tr>
<td>HDL cholesterol (mmol/L)</td>
<td>1.4 ± 0.4</td>
<td>0.8–2.4</td>
</tr>
<tr>
<td>Alcohol intake [frequency % (n)]</td>
<td>62 (21)</td>
<td></td>
</tr>
<tr>
<td>&lt;4 times/mo</td>
<td>1–4 times/wk</td>
<td>29 (10)</td>
</tr>
<tr>
<td>5–7 times/wk</td>
<td>9 (3)</td>
<td></td>
</tr>
<tr>
<td>Cholesterol-lowering medication [frequency % (n)]</td>
<td>18 (6)</td>
<td></td>
</tr>
<tr>
<td>Antihypertensive medication [frequency % (n)]</td>
<td>18 (6)</td>
<td></td>
</tr>
</tbody>
</table>
The correlations of energy intake after skim milk consumption with the mean VAS ratings for fullness, satisfaction, and prospective consumption were −0.42 (P = 0.01), −0.48 (P = 0.004), and 0.57 (P < 0.0001), respectively. The correlations of energy intake after consuming a fruit drink with the mean VAS ratings for fullness, satisfaction, and prospective consumption were −0.24 (P = 0.17), −0.36 (P = 0.04), and 0.24 (P = 0.17), respectively.

**DISCUSSION**

Energy intake at lunch was significantly lower after consuming skim milk than after consuming a fruit drink. This result was supported by self-reports of fullness, satisfaction, and prospective consumption that indicated significantly lower perceived appetite after consumption of skim milk than after consumption of a fruit drink. The study results suggest that consumption of skim milk instead of a fruit drink will lead to increased satiety and decreased energy intake at the next meal.

To our knowledge, this is the first study to show a significant energy reduction at a test meal after consumption of beverages such as skim milk that are commercially available and have not received macronutrient supplementation. The magnitude of the reduction in energy intake after consuming the skim milk (8.5%) as compared with the fruit drink is comparable with the 10–10.5% reduction in energy intake observed in other studies when a test meal was provided 3 h after a preload supplemented with whey, casein, soy, or glucose. However, studies to date do not support this proposal, with no observed effect of calcium on energy intake or appetite in humans (7). Casein has been reported to suppress energy intake equally with whey in one study (10) and less than whey in another (26).

A second means by which skim milk may have suppressed appetite is through the lactose content of the milk. The satiating effect of lactose, as compared with protein, is unclear. One study reported that consumption of preloads containing either lactose or dairy protein did not lead to significant differences in energy intake at a buffet lunch provided 3 h later and that energy intake was significantly decreased after both lactose and dairy protein preloads as compared with intake after a glucose-containing preload (10).

There is also some evidence that highly viscous beverages decrease appetite (27) and energy intake (28). In this study, the higher viscosity of skim milk, compared with the fruit drink, may have contributed to appetite suppression in the skim milk treatment. Finally, there is the question of whether calcium may influence appetite (29). In our study, the skim milk was a rich source of calcium, whereas the fruit drink contained no calcium. However, studies to date do not support this proposal, with no observed effect of calcium on energy intake or appetite in humans (30) or energy intake in rats (31).

A limitation of the study is that participants were not blinded to the beverage that they received. It is possible that participants had preexisting expectations about the effects that each beverage would have on their appetite, and this may have affected appetite ratings. However, the finding that differences between treatments in VAS ratings of fullness and satisfaction became larger over time, as well as the absence of a difference in ratings of prospective consumption, suggests that participants were unlikely to have been exhibiting a socially desirable response bias. If such a bias were affecting results, it is expected that the difference in VAS ratings between treatments would have remained constant over time or perhaps be largest immediately after beverage consumption of skim milk than after consumption of a fruit drink.

**TABLE 3**

<table>
<thead>
<tr>
<th></th>
<th>Mean VAS rating (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skim milk</td>
<td>Fruit drink</td>
</tr>
<tr>
<td>Fullness</td>
<td>68.9 (64.8, 73.0)</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>71.8 (67.4, 76.2)</td>
</tr>
<tr>
<td>Prospective consumption</td>
<td>54.0 (48.3, 59.7)</td>
</tr>
</tbody>
</table>

1 Data are adjusted for baseline values.
2,3 Significantly different from fruit drink: 2P < 0.0001, 3P < 0.05.
ingestion. Furthermore, participants were not informed that their energy intake at the lunch meal would be measured.

The design of this study and the broad inclusion criteria that were implemented increase the generalizability of the results. We recruited overweight and obese men and women from the general population. We did not control for factors such as menopausal status or menstrual cycle status in women. Although this may increase the number of potentially confounding variables, it also allows the results of our study to be potentially applicable to a wide segment of the general population and likely to be robust among different groups.

Future studies might explore whether these findings can be extrapolated to other types of low-fat dairy products, such as yogurt, or to foods and drinks containing proteins other than whey and casein. It would also be useful to explore further the importance of the time lapse between the provision of a beverage and the test meal to observe differences in energy intake.

This study shows that consumption of skim milk leads to increased perceived satiety and decreased energy intake at the next meal, as compared with a fruit drink. The results suggest that replacing sugary drinks with skim milk may influence total energy intake.

The authors’ responsibilities were as follows—ERD: study concept and design; acquisition, statistical analysis, and interpretation of data; drafting and revision of the manuscript; JMH: study concept and design; acquisition, statistical analysis, and interpretation of data; drafting and revision of the manuscript; and obtaining funding; IBP and LJB: study concept and design, statistical analysis, and interpretation of data; drafting and revision of the manuscript; and obtaining funding. None of the authors had a conflict of interest.

REFERENCES

FIGURE 3. Baseline-adjusted mean (±SEM) visual analog scale (VAS) ratings of fullness, satisfaction, and prospective consumption after consumption of skim milk (○) or a fruit drink beverage (▲). The time-by-treatment interaction was statistically significant for fullness (P = 0.015) and satisfaction (P = 0.001) but not for prospective consumption (P = 0.74).