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Research report

Caloric beverages consumed freely at meal-time add calories to an ad libitum meal ☆

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ABSTRACT

The objective was to compare the effects of ad libitum consumption of commonly consumed meal-time beverages on energy and fluid intakes and post-meal average subjective appetite and blood glucose in healthy adults. In a randomized controlled design, 29 males and females consumed to satiation an ad libitum pizza meal with one of five beverages in unlimited amount including water (0 kcal), 1% milk (44 kcal/100 ml), regular cola (44 kcal/100 ml), orange juice (44 kcal/100 ml) and diet cola (0 kcal). Food and fluid intakes were measured at the meal. Average subjective appetite and blood glucose were measured before and for 2 h after the meal. Although energy intake from pizza was similar among all beverage treatments, the amount of fluid consumed (g) varied among the beverages with intake of orange juice higher than regular and diet cola, but not different from water or milk. Meal-time ingestion of caloric beverages, milk, orange juice and regular cola, led to higher total meal-time energy intakes compared to either water or diet cola. Post-meal blood glucose area under the curve (AUC) was lower after milk than after meals with water, orange juice and regular cola and post-meal average subjective appetite AUC was lower after milk than after meals with water. Meal intakes of nutrients including protein, calcium, phosphorus, zinc, vitamins B12, A and D were higher at the meal with milk compared to the other beverages. Thus, caloric beverages consumed ad libitum during a meal add to total meal-time energy intake, but 1% milk favors a lower post-meal blood glucose and average subjective appetite score and adds to nutrient intake.

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Introduction

Several studies in adults and children have suggested that consumption of energy-yielding beverages is associated with positive energy balance, obesity and type 2 diabetes (Gibson & Neate, 2007; Hu & Malik, 2010). Sugar-sweetened beverages have come under particular examination as their consumption now exceeds that of milk and fruit and vegetable juices in the United States (Enns, Goldman, & Cook, 1997; Guthrie & Morton, 2000). Caloric beverages provide approximately 81% of total daily water intake and contribute significantly to overall dietary and calorie intake (Kant, Graubard, & Atchison, 2009; Panel on dietary reference intakes for electrolytes and water, 2004). Based on survey data of dietary records, American adults ages 19 years and older consume an average of about 400 kcal per day from energy-containing beverages including regular soda, energy and sports drinks, milk, 100% fruit juice and fruit drinks (Dietary Guidelines for Americans, 2010; LaComb, Sebastian, Enns, & Goldman, 2011).

The calorie content of beverages varies widely and some including regular sodas, fruit drinks and alcoholic drinks contain calories, but provide little or no essential nutrients. Others, however, such as fat-free or low-fat milk and 100% fruit juice provide nutrients and have a similar energy density (energy per unit weight) to regular soda. To limit excess calories and maintain a healthy weight, the 2010 Dietary Guidelines for Americans advise individuals to drink water and other beverages with few or no calories, in addition to recommended amounts of low-fat or fat-free milk and 100% fruit juices (Dietary Guidelines for Americans, 2010). Similarly, the Beverage Guidance Panel created a beverage hierarchy to guide beverage consumption, recommending water as the primary choice followed by calorie-free tea or coffee, then low-fat milk and soy beverages, non-caloric sweetened beverages, caloric beverages with some nutrients and lastly, sugar or high fructose corn syrup sweetened beverages (Popkin et al., 2006).

Energy-yielding beverages are commonly used as snacks, meal accompaniments or meal replacements. Although energy from

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beverages has been claimed to be less satiating than that from solid foods in some studies (Mattes, 2006) and hypothesized to bypass intake regulatory systems (Anderson & Woodend, 2003), there is still no agreement on the impact of liquid calories on energy intake (Anderson, 2006). The majority of studies examining the effect of beverages on appetite and food intake have been conducted on beverages alone prior to a meal (Almiron-Roig, Flores, & Drewnowski, 2004; Harper, James, Flint, & Astrup, 2007; Panahi et al., 2013; Rolls, Kim, & Fedoroff, 1990). One report has shown that caloric beverages consumed at meal-time do not affect the amount of food eaten at an ad libitum meal, however, in this report the amount was controlled to isovolumetric amounts (360 ml) of water, diet cola, regular cola, fruit juice, and 1% milk (DellaValle, Roe, & Rolls, 2005). Energy intakes from the lunch-time foods were not different among the beverages, but total energy intakes with caloric beverages were higher than non-caloric beverages (DellaValle et al., 2005). A limitation of these prior studies is that they have not allowed thirst to be a factor in beverage intake during a meal. The effect of ad libitum consumption of beverages at meal-time on energy intake has not been reported.

Although the past focus has been primarily on the energy contribution of beverages to excess energy intake, it is also shown that carbohydrate containing beverages raise blood glucose, which is of concern due to the high prevalence of insulin resistance (Hu & Malik, 2010). However, the effect of their macronutrient composition on blood glucose has received little attention. We previously showed that isovolumetric amounts (500 ml) of 2% milk given prior to a meal reduced post-meal blood glucose in healthy men and women compared to other beverages including chocolate milk, soy beverage, orange juice, infant formula and water (Panahi et al., 2013), suggesting a benefit to milk beyond its calories and nutrient contribution to a meal. This may be attributed to its protein content as milk proteins, when consumed alone in beverage form or with carbohydrate, reduce glycemic response (Akhavan, Luhovyy, Brown, Cho, & Anderson, 2009; Nuttall, Mooradian, Gannon, Billington, & Krezowski, 1984; Promintzer & Krebs, 2006). The effect of beverages consumed ad libitum as part of a meal on post-prandial satiety and blood glucose concentrations has not been reported.

We hypothesized that consuming caloric beverages ad libitum and reflecting thirst, as part of a meal, reduces meal-time food intake, post-meal subjective appetite and glycemic response in healthy young adults. Therefore, the objective of the present study was to compare the effects of ad libitum consumption of water, 1% milk, regular cola, diet cola, and orange juice at a pizza meal on ad libitum energy and fluid intake, and post-meal subjective appetite and glycemic response in healthy young men and women.

Subjects and methods

Subjects

Participants were recruited through advertisements posted from the University of Toronto campus. Men and women between 20 and 30 years of age with a body mass index (BMI) of 20–24.9 kg/m^2 were eligible to participate. Exclusion criteria included smoking, dieting, skipping breakfast, lactose intolerance or allergies to milk, diabetes (fasting blood glucose $\geqslant$7.0 mmol/l) or other metabolic diseases that could interfere with study outcomes. Restrained eaters, identified by a score of $\geqslant$11 on the Eating Habits Questionnaire (Herman & Polivy, 1980), and those taking medications were also excluded. The sample size required was based on previous short-term food intake studies on milk protein (Akhavan et al., 2009; Anderson, Tecimer, Shah, & Zafar, 2004) to detect a 150 kcal difference in food intake with a power of 0.90 and an alpha of <0.05. Participants were financially compensated for completing the study. The procedures of the study were approved by the Human Subject Review Committee, Ethics Review Office at the University of Toronto.

Beverages

Beverages included: (1) water (control); (2) milk (1% M.F.) (Neilson Dairy; ON, Canada); (3) regular cola (Coca Cola Canada Ltd.; ON, Canada); (4) diet cola (Coca Cola Canada Ltd.; ON, Canada); and (5) orange juice (Tropicana Pure Premium, no pulp; Tropicana Products Inc., Bradenton, Florida, United States). The nutritional composition of each beverage is outlined in Table 1. All beverages were served ad libitum in 500 ml containers. Beverages were served chilled.

Protocol

A standard breakfast (300 kcal) consisted of a single serving of a ready-to-eat breakfast cereal (Honey Nut Cheerios; General Mills, Mississauga, Canada), a 250 ml box of 2% milk (Sealtest Skim Milk, Markham, Canada) and a 250 ml box of orange juice (Tropicana Pure Premium, no pulp; Tropicana Products Inc., Bradenton, Florida, United States). Breakfasts were given to participants to be consumed at their preferred time in the morning (0600–0900) after a 12 h overnight fast and were asked not to consume any food between the breakfast and the study session 4 h later (1000–1300), but were permitted to drink water until 1 h before the session. Participants attended the Department of Nutritional Sciences at the University of Toronto for the sessions. To minimize within subject variability, all participants were scheduled to arrive at the same time and on the same day of the week for each treatment and instructed to refrain from alcohol consumption and to maintain the same dietary and exercise patterns the evening before each test. To ensure that these instructions were followed, participants completed a questionnaire detailing pre-session information about their diet and lifestyle patterns. Because impaired insulin sensitivity has been observed after an oral glucose tolerance test in the luteal phase of the menstrual cycle in healthy women (Escalante Pulido & Alpizar Salazar, 1999), women were scheduled for the sessions during their follicular phase. The beverages were provided in random order once per week for men and for women, in random order once per week during the first 2 weeks of their menstrual cycles.

On arrival, participants completed visual analog scale (VAS) questionnaires assessing their "Sleep Habits", "Stress Factors", and "Food Intake and Activity Level" over the previous 24 h before the study session as well as their activity since waking up, "Feelings of Fatigue", "Thirst" and "Motivation to Eat". The Motivation

Table 1
Nutritional composition of beverages.

Nutrients[a]	Beverages			
	Milk (1% M.F.)	Regular cola	Diet cola	Orange juice
Energy (kcal)	110	110	0	110
Fat (total) (g)	2.5	0	0	0
Saturated fat (g)	1.5	0	0	0
Trans fat (g)	0	0	0	0
Sodium (mg)	120	30	35	0
Carbohydrate (g)	12	30	0	27.5
Sugars (total) (g)	12	30	0	23
Protein (g)	9	0	0.1	2.1
Calcium (mg)	330	0	0	16

[a] Nutrient content of each beverage as provided by the manufacturer. Amounts given are per 250 ml serving.

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