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Research report

Energy and macronutrient content of familiar beverages interact with pre-meal intervals to determine later food intake, appetite and glycemic response in young adults ☆

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ABSTRACT

The objective was to compare the effects of pre-meal consumption of familiar beverages on appetite, food intake, and glycemic response in healthy young adults. Two short-term experiments compared the effect of consumption at 30 (experiment 1) or 120 min (experiment 2) before a pizza meal of isovolumetric amounts (500 mL) of water (0 kcal), soy beverage (200 kcal), 2% milk (260 kcal), 1% chocolate milk (340 kcal), orange juice (229 kcal) and cow's milk-based infant formula (368 kcal) on food intake and subjective appetite and blood glucose before and after a meal. Pre-meal ingestion of chocolate milk and infant formula reduced food intake compared to water at 30 min, however, beverage type did not affect food intake at 2 h. Pre-meal blood glucose was higher after chocolate milk than other caloric beverages from 0 to 30 min (experiment 1), and after chocolate milk and orange juice from 0 to 120 min (experiment 2). Only milk reduced post-meal blood glucose in both experiments, suggesting that its effects were independent of meal-time energy intake. Combined pre- and post-meal blood glucose was lower after milk compared to chocolate milk and orange juice, but did not differ from other beverages. Thus, beverage calorie content and inter-meal intervals are primary determinants of food intake in the short-term, but macronutrient composition, especially protein content and composition, may play the greater role in glycemic control.

Introduction

The prevalence of obesity and overweight in the Canadian population has doubled over the past 25 years, while per capita milk consumption has decreased (Ontario Per Capita Consumption of Milk & Cream, 2011). Similarly, in the United States milk consumption has decreased (Sebastian, Goldman, Enns, & LaComb, 2010) and energy-containing sweetened beverages have increased (Almiron-Roig, Chen, & Drewnowski, 2003; Malik & Hu, 2012). Many population studies of recent years have associated higher milk and dairy intake with healthier body weights and reduced risk of developing characteristics of the metabolic syndrome including hyperglycemia (Drapeau et al., 2004; Pereira et al., 2002). Based on the composition of milk (Akhavan, Luhovyy, Brown, Cho, & Anderson, 2009; Ebringer, Ferencik, & Krajcovic, 2008), this may be causally based.

In Canada and the United States, cow's milk, soy beverages, orange juice and water have been recommended over sugar-sweetened beverages for both adults and children. The Beverage Guidance Panel created a beverage hierarchy to guide beverage consumption, with water as a 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). However, this was not based on comparisons of these frequently consumed beverages on food intake and metabolic regulation. Furthermore, in spite of the high sugar content, fruit juices such as orange juice are often considered healthy beverages.

Sugar composition and protein content are major determinants of the blood glucose and insulin responses and subjective appetite and food intake (Akhavan et al., 2009; Monsivais, Perrigue, & Drewnowski, 2007; Wolever & Miller, 1995). Glucose alone is more

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glycemic than sucrose or lactose and protein, when consumed with carbohydrate, reduces subsequent glycemic response (Frid, Nilsson, Holst, & Bjorck, 2005; Nilsson, Stenberg, Frid, Holst, & Bjorck, 2004; Nilsson, Holst, & Bjorck, 2007; Promintzer & Krebs, 2006). Yet, there have been no reports on usually consumed beverages differing in composition on later food intake (Almiron-Roig & Drewnowski, 2003; Dove et al., 2009; Harper, James, Flint, & Astrup, 2007). Isocaloric (248 kcal) servings of orange juice, regular cola, and 1% milk when compared with sparkling water given 2 h 15 min before a meal showed no differences in ad libitum food intake (Almiron-Roig & Drewnowski, 2003), but this study did not consider the nutritional merits of these beverages. Milk products provide not only more essential nutrients than juices or other beverages, but also proteins (whey protein and casein) that contribute to glycemic control (Akhavan et al., 2009; Hall, Millward, Long, & Morgan, 2003; Karamanlis, Chaikomin, Doran, & Bellon, 2007) and satiety and reduce food intake (Akhavan et al., 2009; Anderson, Tecimer, Shah, & Zafar, 2004). However, in contrast to data on the second-meal effect of solid food consumption on reducing post-meal glycemic response (Jenkins et al., 1982; Mollard, Wong, Luhovyy, & Anderson, 2011), there are no reports of the effects of pre-meal consumption of beverages on post-meal glycemia as a marker of metabolic control and post-meal satiety. Post-meal glycemia is important for achieving overall glycemic control and has been independently associated with adverse metabolic outcomes (Ceriello & Colagiuri, 2008).

Therefore, we hypothesized that both energy and the macronutrient composition of recommended beverages when consumed before and between meals is a factor in the regulation of appetite, food intake, and post-meal glycemic response. The objective of the present study was to investigate the effects of isovolumetric amounts, representing two serving sizes, of 2% milk, 1% chocolate milk, a soy beverage, infant formula (based on cow's milk but with 1% vs 3% protein and with an increased whey to casein ratio), orange juice and water on food intake either 30 or 120 min later as well as on subjective appetite and glycemic response pre- and post-meal in healthy young men and women.

Subjects and methods

Subjects

Participants were recruited through advertisements posted on the University of Toronto campus. Men and women between 20 and 30 years of age with a body mass index (BMI) of 20 to 24.9 kg/m^2 were eligible to participate. Exclusion criteria included smoking, dieting, skipping breakfast, lactose intolerance, allergies to milk or soy, 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 et al., 2004). Subjects 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 isovolumetric amounts (500 mL) of the following: (1) water (control); (2) milk (2% M.F) (Neilson Dairy; ON, Canada) because it is the most commonly consumed type of milk amongst Canadians; (3) chocolate milk (1% M.F.) (Neilson Dairy; ON, Canada) because it is the most commonly consumed flavored milk; (4) soy beverage (Silk Soy Beverage: Original; Broomfield, CO) because it is an alternative for individuals who are vegetarian or lactose-intolerant; and (5) cow's milk-based infant formula (Enfamil; Mead Johnson Nutrition & Company, ON, Canada) because it mimics breast milk in protein content and in the ratio of whey to casein. In experiment 2, orange juice (Tropicana Pure Premium, no pulp; Tropicana Products Inc., Bradenton, Florida, United States) was also provided for three reasons. First, it is the most commonly consumed fruit juice and is a recommended beverage. Second, sugar sweetened beverages have been hypothesized to by-pass food intake regulatory systems (Anderson & Woodend, 2003), but no comparison of non-carbonated sweetened beverages with beverages of more complex compositions have been reported. Third, the objective was to compare the effects of chocolate milk with orange juice, which has similar sugar content but is absent of protein, in order to examine whether chocolate milk confers glycemic benefits despite its sugar content. The nutritional composition of each beverage is outlined in Table 1. All beverages were isovolumetric (500 mL) representing two servings (cups). Beverages were served chilled.

Protocol

Participants attended the Department of Nutritional Sciences at the University of Toronto following a 12 h overnight fast, except for water, which was permitted until 1 h before each session. 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, subjects completed a questionnaire detailing pre-session information about their diet and lifestyle patterns. Because impaired insulin sensitivity has been observed after an oral

Table 1
Nutritional composition of beverages.

Nutrients[a]	Beverages				
	Chocolate milk (1% M.F.)	Milk (2% M.F.)	Soy beverage	Infant formula[b]	Orange juice
Energy (kcal)	340	260	200	368.2	229
Fat (total) (g)	5	10	8	19.1	0
Saturated fat (g)	3	6	1	8.1	0
Trans fat (g)	0	0.2	0	0	0
Cholesterol (mg)	20	40	0	12.0	0
Sodium (mg)	240	240	240	98.4	0
Carbohydrate (g)	56	24	16	39.6	54
Fiber (total) (g)	0	0	2	0	0
Sugars (total) (g)	56	24	12	39.6	46
Protein (g)	18	18	14	7.6	4

[a] Nutrient content of each beverage as provided by the manufacturer. Amounts given are per 500 mL serving.
[b] Powdered infant formula prepared according to manufacturer label instructions.