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Beverages contribute extra calories to meals and daily energy intake in overweight and obese women

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HIGHLIGHTS

- It is unclear if humans reduce solid food intake to offset calories from beverages.
- Overweight and obese women completed diet records for seven consecutive days.
- Solid food intake was unrelated to caloric beverage intake within meals or days.
- Beverages contributed to total energy intake in a near-additive fashion.
- No evidence of compensation was found, either within meals or across entire days.

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ABSTRACT

Caloric beverages may promote obesity by yielding energy without producing satiety, but prior laboratory and intervention studies are inconclusive. This study examined whether the diets of free-living overweight and obese women show evidence that calories from beverages are offset by reductions in solid food within individual eating occasions and across entire days. Eighty-two women weighed and recorded all consumed foods and beverages for seven days. Beverages were coded as high-calorie (≥0.165 kcal/g) or low-calorie (<0.165 kcal/g), and total energy intake and energy intake from solid food were calculated for each eating occasion and day. In covariate-adjusted models, energy intake from solid food did not differ between eating occasions that included high-calorie or low-calorie beverages and those with no reported beverage. Energy intake from solid food was also unrelated to the number of high-calorie or low-calorie beverages consumed per day. On average, eating occasions that included a high-calorie beverage were 169 kcal higher in total energy than those with no reported beverage, and 195 kcal higher in total energy than those that included a low-calorie beverage. Each high-calorie beverage consumed per day contributed an additional 147 kcal to women's daily energy intake, whereas low-calorie beverage intake was unrelated to daily energy intake. Beverages contributed to total energy intake in a near-additive fashion among free-living overweight and obese women, suggesting a need to develop more effective interventions to reduce caloric beverage intake in the context of weight management, and to potentially reexamine dietary guidelines.

1. Introduction

The obesity epidemic has largely resulted from changes in dietary consumption patterns [1,2]. In particular, beverages have increased in portion size by 25–34% since the late 1970s and become more readily available in the environment [3–6]. As a result, the percentage of daily energy from caloric beverages has increased by 135% over the past 3 decades [7]. Despite the compelling temporal trends implicating caloric beverages in the obesity epidemic, the scientific literature remains unclear with respect to the contribution of caloric beverages to total energy intake and body weight at the individual level. Two meta-analyses found small but significant overall associations between intake of sugar-sweetened beverages and total energy intake

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and body weight [8,9], whereas two more restrictive meta-analyses that excluded cross-sectional studies reported that the association between sugar-sweetened beverage intake and weight gain was "inconclusive" [10] or "near zero" [11].

In the absence of a conclusive link between caloric beverage intake and body weight, attention has shifted to examining whether individuals consume less solid food to offset the energy obtained from caloric beverages. If reductions in solid food intake do not fully offset the energy consumed from beverages, caloric beverages would have a positive net effect on energy balance and promote weight gain. Most studies addressing this question administered beverages or solid foods, often matched on energy and macronutrient content, and then assessed whether individuals consumed less solid food at a subsequent test meal. Results are mixed; some studies report that consuming caloric beverages led to smaller reductions in subsequent test meal intake than consuming solid foods [12–15], suggesting weak dietary compensation for caloric beverages, whereas others did not support this pattern [16]. Importantly, the time interval between beverage consumption and test meal intake may affect the degree of observed compensation since beverages are found to be less satiating than solids at longer delays [17]. However, minimal compensation has also been observed for beverages consumed *simultaneously* with solid food [18].

The existing literature has four major limitations. First, most studies involved mandated consumption of specific beverages and/or solid foods, or assessed compensation using a standardized test meal presented in highly-controlled laboratory settings. These designs have limited generalizability to real world settings where greater food variety can trigger eating in the absence of hunger [19,20]. Second, studies often examined the effect of beverages on intake at subsequent test meals, which differs from the common practice of consuming beverages with solid food during a meal. Third, laboratory studies are limited in duration, and do not provide information on dietary compensation for beverages across an entire day. Finally, very few studies have specifically examined dietary compensation for caloric beverages in overweight and obese individuals, a group that may have a reduced compensation for beverages [21] and for whom the potential effects of caloric beverages on energy intake are particularly relevant to weight management.

The aim of this observational study was to test the hypothesis that compensation for caloric beverages occurs within eating occasions and across days. Free-living overweight and obese women weighed and recorded all foods and beverages consumed over seven consecutive days. Consistent with dietary compensation, we hypothesized that individuals would exhibit lower intake of solid food to offset the energy consumed from beverages, resulting in no overall difference in total energy intake within the same eating occasion or within the same day. Dietary compensation would be apparent in four hypothesized patterns of association:

1) Energy intake from solid food would be lower at eating occasions that included a high-calorie beverage compared to eating occasions with no reported beverage or a low-calorie beverage.
2) Total energy intake at eating occasions that included a high-calorie beverage would not significantly differ from eating occasions with low-calorie beverages or no beverage.
3) Daily energy intake from solid food would be inversely associated with the number of high-calorie beverages consumed, and unrelated to the number of low-calorie beverages consumed.
4) No association was expected between the number of high-calorie or low-calorie beverages consumed and total daily energy intake.

2. Methods

2.1. Participants

Overweight and obese women were recruited for a study on behavioral predictors of dietary intake between 2008 and 2010 [22] through study advertisements posted on medical center campuses and online posting forums. Women aged 18 to 45 years with a body mass index (BMI) between 25.0 and 39.9 kg/m^2 were eligible for participation. Exclusion criteria included recent dieting, major food allergies or sensitivities, pregnancy or lactation in the past six months, symptoms of eating pathology in the past 5 years, clinically significant symptoms of depression, anxiety, or mania in the past 30 days, bariatric surgery, peri- or post-menopausal status, or medical conditions or medications affecting appetite, metabolism, or digestion. Eligibility criteria were assessed through an initial telephone screening interview. Study procedures received Institutional Review Board approval.

2.2. Procedures

Participants completed two laboratory visits. In the first visit, written consent was obtained and height and weight were assessed as a final step in verifying eligibility. Participants were trained to complete weighed diet records using plastic food models, a portable, digital food scale (model # P115, Escali, Minneapolis, MN), and record forms with spaces for each item's description, brand or source, preparation method, time of consumption, amount consumed (in grams), and whether it was consumed as a meal, snack, or beverage consumed alone. Weighed diet records are preferable to other methods, such as 24-hour diet recalls and food frequency questionnaires, for quantifying actual dietary intake within a particular period of time [23,24]. Participants were not required to record water intake because this can be burdensome and difficult for participants, and water consumption does not affect solid food intake or satiation at a meal [18,25–27]. Participants were asked to complete seven consecutive days of diet recording. Research assistants contacted participants by telephone twice between visits to promote compliance with the diet record protocol. During the second study visit, diet records were reviewed for completeness and any ambiguities were resolved. Participants were then debriefed and compensated $50 for their time.

2.3. Measures

2.3.1. Body mass index (BMI)

BMI (kg/m^2) was calculated from height and weight measured in light clothing and without shoes using a balance beam scale and stadiometer.

2.3.2. Socioeconomic and demographic variables

Participants' self-reported age, education level (baccalaureate degree vs. less than baccalaureate degree), household income ($0–$29,999; $30,000–$59,999; $60,000–$89,999; $90,000 and above), race/ethnicity (Asian; Black/African-American; Hispanic; Multi-ethnic/Other; Non-Hispanic, White), and marital status (single, separated or divorced vs. married or living with partner) were measured.

2.3.3. Physical activity

The self-administered short-form of the International Physical Activity Questionnaire [28] was used to assess occupational and leisure time physical activity for the seven days during which dietary intake was recorded. For each subject, average daily minutes spent engaged in moderate and vigorous physical activity (combined) was calculated.

2.3.4. Dietary intake

Analysis of diet record data was completed using Food Processor SQL version 10.5.0 (ESHA Research, Salem, OR). A research assistant used item descriptions and weights provided by participants to identify and enter all consumed foods and beverages. Plate waste and inedible portions of foods (e.g., apple cores) were accounted for through subtraction. Foods sharing the same time of day on the diet record were considered to belong to the same eating occasion. A registered dietitian reviewed all dietary data for accuracy.