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Caloric compensation for sugar-sweetened beverages in meals: A population-based study in Brazil

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A B S T R A C T

Sugar-sweetened beverage (SSB) consumption can cause positive energy balance, therefore leading to weight gain. A plausible biological mechanism to explain this association is through weak caloric compensation for liquid calories. However, there is an ongoing debate surrounding SSB calorie compensation. The body of evidence comes from a diversity of study designs and highly controlled settings assessing food and beverage intake. Our study aimed to test for caloric compensation of SSB in the free-living setting of daily meals. We analyzed two food records of participants (age 10 years or older) from the 2008–2009 National Dietary Survey (Brazil, $N = 34{,}003$). We used multilevel analyses to estimate the within-subject effects of SSB on food intake. Sugar-sweetened beverage calories were not compensated for when comparing daily energy intake over two days for each individual. When comparing meals, we found 42% of caloric compensation for breakfast, no caloric compensation for lunch and zero to 22% of caloric compensation for dinner, differing by household per capita income. In conclusion, SSB consumption contributed to higher energy intake due to weak caloric compensation. Discouraging the intake of SSB especially during lunch and dinner may help reduce excessive energy intake and lead to better weight management.

1. Introduction

Over the past decades, diet and lifestyle have changed dramatically. Trends in diet include the increased availability of low-cost food and drinks that are high in energy and rapidly absorbed sugar (Malik, Willett, & Hu, 2013). Examples of such drinks are sugar-sweetened beverages (SSBs), the consumption of which has been growing in Brazil as well as in other parts of the world (Basu, McKee, Galea, & Stuckler, 2013; Pereira, Souza, Duffey, Sichieri, & Popkin, 2015). SSB leads to positive net energy balance and has been recognized as an important contributor to the diabetes and obesity epidemics (Hu & Malik, 2010; Te Morenga, Mallard, & Mann, 2013).

One explanation for why SSBs cause weight gain is weak caloric compensation. Complete caloric compensation (100%) occurs when solid food calories are reduced to compensate for an equal number of liquid calories added to a diet. In a crossover design experiment where subjects consumed the same amount of calories from soft drinks or jellybeans every day for four weeks, the energy intake from SSB did not lead to an equivalent reduction in the energy intake of other foods (DiMeglio & Mattes, 2000).

Despite the evidence of weak caloric compensation of SSB, the topic remains open for debate. One criticism is that most studies addressing SSB's effects on energy intake have been conducted in artificial settings. This limitation was mentioned as an argument against generalizing conclusions for a real life eating environment by the 2010 Dietary Guidelines Advisory Committee—U.S. Department of Agriculture, U.S. Department of Health and Human Services—and thus for withholding stronger recommendations on SSB intake (Slavin, 2012).

Moreover, there is a lack of consensus regarding measurement of caloric compensation for SSB, leading to different conclusions. The body of evidence on SSB caloric compensation comes from a diversity of study designs, protocols and outcome measurements (Dennis, Flack, & Davy, 2009; Vartanian, Schwartz, & Brownell, 2007). Therefore, some studies measured caloric compensation over a single meal, others over an entire day (Jones & Mattes, 2014;

Abbreviations: SSB, sugar-sweetened beverage.

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Mourao, Bressan, Campbell, & Mattes, 2007; Zheng et al., 2015). There are also long-term studies measuring compensation over weeks of intervention (DiMeglio & Mattes, 2000; Reid, Hammersley, Hill, & Skidmore, 2007; Van Wymelbeke, Béridot-Thérond, de La Guéronnière, & Fantino, 2004). Some SSB preload studies measured energy intake from a single dish or small selection of sandwiches and fruits, others from ad libitum buffets with a large selection of food (Cassady, Considine, & Mattes, 2012; DellaValle, Roe, & Rolls, 2005; Ranawana & Henry, 2010). Additionally, the conclusions on caloric compensation of SSB varied between studies. For example, one study found differences by sex. Caloric compensation from pre-load SSB in meals observed for men ranged from 99% to 116% and for women ranged from 7% to 85% (Ranawana & Henry, 2010).

We aimed to overcome limitations of the existing literature on caloric compensation by comparing individuals' intake over two days, as a strategy to diminish confounding bias. We analyzed data from a national dietary survey, reflecting the free-living settings of daily meals, in the subjects' real environments. In addition, we measured caloric compensation for SSB over an entire day and over meals in the same dataset.

2. Methods

2.1. Study sample

This study analyzed data from the 2008–2009 National Dietary Survey conducted by the Brazilian Institute of Geography and Statistics in a subsample of households investigated in the 2008–2009 Brazilian Household Budget Survey. The main sample was obtained by a two-stage complex cluster sampling design. Primary sampling units were census tracts, selected by proportional probability to the number of households based on the 2000 Brazilian Demographic Census, and secondary sampling units were households, selected by simple random sampling. Dietary data was collected from 25% of households from the main sample, randomly selected, totaling a nationwide representative sample of 13,569 households. Total participants included 34,003 individuals age 10 years or older who completed two food records on non-consecutive days over the same week. The participants described all types of food and beverages consumed in 24 h, including the amount consumed, cooking method when applicable, time of day and location. A detailed protocol of the survey is found elsewhere (Instituto Brasileiro de Geografia e Estatística [IBGE], 2011a; Pereira et al., 2015).

2.2. Sugar-sweetened beverages and meal selection

For this study, sugar sweetened beverages (SSBs) included soft drinks (cola and non-cola sodas, *guaraná* sodas, *mate* tea drinks) and natural and industrialized fruit juices. The energy content of each food and beverage item consumed was estimated using the Nutritional Composition of Food Consumed in Brazil (IBGE, 2011b). We took into account table sugar added to non-ready-to-drink beverages. Participants were asked whether they usually add sugar, artificial sweeteners, or nothing to their beverages. Ten grams of sugar for each 100 ml of beverage was considered for sugar users; and five grams of sugar for each 100 ml of beverage was considered for users of both sugar and artificial sweeteners (Pereira et al., 2015).

We measured caloric compensation for SSB over an entire day and over meals. For the analyses of caloric compensation over an entire day, we obtained total daily energy intake (kcal), daily energy intake from food (kcal), daily energy intake from SSB (kcal) and day of the week (weekday or weekend), for each day. Food included all non-SSB items reported.

For the analysis based on meals, we calculated the total energy intake (kcal) of an eating occasion by summing the energy content of food and beverages consumed during the same time of day. We identified three main periods of consumption: breakfast (3 a.m.–10 a.m.), lunch (11 a.m.–1 p.m.), and dinner (6 p.m.–9 p.m.). The majority of subjects reported only one eating occasion per period of day. For those who reported more than one eating occasion within a given period (11% during breakfast, 10% during lunch, and 18% during dinner), the eating occasion with the highest energy intake was selected to represent that meal. For example, if a subject consumed 100 calories at 11 a.m. and 500 calories at 1 p.m., we selected the 1 p.m. eating occasion to represent that period's meal. The selected meals were then analyzed to test for caloric compensation. Together, the three meals represented on average 83% (Standard deviation [SD] = 14) of the total number of eating occasions of that day, 87% (SD = 16) of the total energy intake of that day, and 78% (SD = 36) of the total number of occasions with reported SSB during that day.

Meals selected were categorized as “with reported SSB” or “without reported SSB”. For each period, participants that registered meals over two days were classified in one of three ways: “no SSB intake”, “SSB in one day” and “SSB in both days”. For each meal, we obtained total energy intake (food + SSB, kcal), food intake (kcal) and SSB intake (kcal). Other variables of the meal were: day of the week (weekday or weekend); time of day; location (at home or away from home); energy intake (kcal) of the previous meal (eating occasion during the same day reported just prior to the analyzed meal) and time interval since the previous meal (hours). The latter two variables were proxies for pre-meal hunger. We used a univariate regression analysis to compare Day 1 and Day 2 means within each SSB pattern for each meal (Table 2).

2.3. Data analysis

We used a multilevel linear regression to test for caloric compensation. In the random-intercept model, the outcome was food energy intake (kcal) and the explanatory variable was SSB intake (kcal). Caloric compensation was then interpreted from the coefficient for the SSB intake variable obtained in the regression model. In other words, for every one kcal of SSB added to a meal we obtained the related calories from food, and translated it into the percentage of SSB calories that were compensated.

We estimated caloric compensation by creating two variables: the within- and between-subject components of the explanatory variable SSB intake. The between-subject component was the subject mean of SSB intake $\overline{X}_{\cdot j}$ and the within-subject component was the deviation from the subject mean of SSB intake $X_{ij} - \overline{X}_{\cdot j}$ (Neuhaus & Kalbfleisch, 1998). Both variables, the within- and the between-subject components of SSB, replaced the SSB intake variable in the model. The pair of coefficients, the within-subject β_X^W and the between-subject β_X^B components, were then formally tested for equality. We used a test for linear combinations of coefficients, in which the null hypothesis is: $H_0 : \beta_X^W - \beta_X^B = 0$. For any of the models, the equality test for the coefficients found that within- and between-subject effects were not equal. Thus, we considered the within-subject coefficient less biased to interpret the results of the random-intercept regression model (Begg & Parides, 2003; Neuhaus & Kalbfleisch, 1998). An advantage of this method is estimating within-subject effects that are not prone to subject-level confounding (time-invariant variables). All stable characteristics of the subjects, observed or not, were controlled for because only within-subject variation is used to estimate within-subject effects. This approach aimed to reduce bias as each subject truly acts as his/her own control for time-invariant variables. In this case, the subject is held constant in the comparison (Rabe-