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Liquid calories, energy compensation, and weight: what we know and what we still need to learn

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Roughly 10,000 years ago, sugar was first domesticated in New Guinea. Roughly 8,000 years ago it was transplanted to India. Sometime around the seventh century, cultivation and some industrial production began in southern Europe, and the crusades subsequently acquainted more Europeans with sugar imported from Arab lands. Through the 16th century, sugar was often viewed by Europeans as having medicinal properties. Colonization of the new world led to mass production and distribution and sugar as a major foodstuff[1–5]. By 1713, a writer in a scholarly journal was extoling the health virtues of high levels of sugar consumption, including in beverages[6]. In 1893, Harley[7] conducted self-experiments and concluded that consumption of 250 g (~4184 kJ, or ~1,000 kcal) of sugar greatly increased muscular work capacity. In 1899 it was reported that in a controlled trial in soldiers, those given a ration of sugar were in better health, felt more vigorous, and gained more weight (presumably judged to be a good thing at the time)[8]. As the century turned, Gardner[9] described sugar as a nutritional necessity that increased the health and vigor of populations. Yet the positive health halo of sugar would not last. A generation later, authors of scientific papers would write about “The social problem growing out of the overconsumption of sugar” and described school-based programs to teach children to consume less sugar[10].

Sugar consumed in liquid form has come to be seen by some as especially deserving of scrutiny. In 1990, Tordoff and Alleva[11] published seminal trial results showing that persons required to consume additional sugar in the form of a beverage gained more weight than did a control group given a noncaloric beverage. Thirteen years later, suspicion was increasing that metabolizable energy, perhaps especially sugar, consumed as liquids promoted less satiety, less energy compensation, and more weight gain than did the same energy consumed in solid form[12]. The topic has become controversial to say the least[13], and there is substantial evidence that the strength of the supporting data has often been exaggerated and distorted[14,15].

Newspaper articles offer statements such as “People who drink sugary soft drinks do not appear to compensate by reducing calories somewhere else in their diets, so they tend to pack on extra pounds”[16] and “Study after study has shown that like experimental animals, people do not compensate for extra liquid calories by eating less food”[17]. This concept, that people do not adjust their energy intake (or expenditure) to compensate for energy consumed as liquids is at the heart of the matter. Yet, is it true? Though opinions on matters

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of energy compensation in response to various forms of sugar intake and/or liquid energy have been offered for over 70 years[18] [19], convincing data on these issues has been scarce.

In this issue of the *Journal*, Reid *et al.*[20] offer a new and valuable piece of evidence on this question. In a study of obese adult women, those consuming sugar in liquid form at a level of 1800 kJ (~430 kcal) per day gained far less weight than expected and no more weight than did women in a control group drinking zero-calorie beverages. The study has several strengths. It was a controlled trial that was run for long enough to observe weight changes and that was at least partially conducted in a blinded fashion. It also has several limitations, including a modest sample size, incomplete blinding, and the fact that it was not strictly randomized. I will not belabor those points here as Reid and colleagues discuss them in their article. Note also that the study only concerns adult women and cannot necessarily tell us about effects in men or children.

What does the study show?

The study's essential finding concerns the question of compensation for liquid calories. The sucrose group gained no appreciable weight. This shows that over an extended period, at least in conditions like those of this study, women do compensate for additional calories consumed in the form of a sugar-sweetened beverage (SSB). Moreover, that the weight gained in the sucrose group was significantly less than that predicted by an established mathematical model based on the number of calories consumed in the form of SSBs, further indicates that the vast majority of the energy consumed was compensated for. Reid *et al.* state "Obese women who received 1800 kJ sucrose per day in soft drinks for four weeks gained a mean of 1.72 kg less than predicted by the model." Interestingly, the model predicted a total weight gain for a woman with the average characteristics listed in Reid *et al.*'s Table 1 of only about 1.8 kg.

Are the findings consistent with those of other studies?

Yes. Kaiser *et al.*[15] meta-analyzed other studies in which adults were required to consume additional energy in SSBs in randomized controlled trials (RCTs) and found that, on average, such required SSB consumption did indeed cause weight gain, but that the amount of weight gained was far less than half the amount one would have predicted to be gained by use of the same mathematical model used by Reid *et al.* (see Kaiser *et al.*'s Figure 2). This indicates that, as Reid *et al.* found, over extended periods of time, the majority of the energy consumed as SSBs is indeed compensated for.

Do the findings inform us about the effects of reducing SSB consumption among adult women?

No. Though tempting, we cannot necessarily infer the effects of reducing SSB consumption from studies of the effects of increasing SSB consumption. That said, as Kaiser *et al.*[15] reported, no RCT of adults reported to date has found a statistically significant effect of reducing SSBs on weight.

Do the findings inform us about the differential effects (if any) of consuming liquid versus solid calories on weight?

No. The results of Reid *et al.* only show what happens with SSBs. From these data alone, we have no way of knowing whether the same results would have been obtained if the women were required to consume 1,800 kJ of food in some solid form. Returning to the literature at large, there is evidence from a recent meta-analysis that in short-term (typically single day) studies with food intake as the outcome, liquid calories are less well compensated for than are solid calories[21]. Yet, we cannot assume that individuals will not adapt to dietary changes over time. Longer term effects on weight cannot be reliably inferred from short-term effects on food intake. Indeed, to my knowledge, there are only two human RCTs comparing the effects of liquid versus solid foods on weight over an extended period of time and neither found a statistically significant difference between the liquid and solid conditions when the entire samples were analyzed[22,23].

In conclusion, what we know from the overall literature is that when adults are required to consume additional energy in the form of SSBs, on average, they gain some weight. What we also know from the overall literature and this new study is that, on average, they gain far less weight than they would be expected to gain if they did not compensate. Thus, people clearly do compensate for liquid calories; although they do so incompletely. What we do not know, despite all the drama and vituperation surrounding SSBs, is whether, over extended periods of time, people compensate any differently for liquid versus solid calories. It is high time we learned.

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