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Invited Commentary

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 8000 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. Until the sixteenth century, sugar was often viewed by Europeans as having medicinal properties. Colonisation of the New World led to mass production and distribution of sugar as a major foodstuff[1–5]. By 1713, a writer in a scholarly journal was extolling 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 (approximately 4184 kJ or approximately 1000 kcal) of sugar greatly increased muscular work capacity. In 1899, a controlled trial involving soldiers reported that 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 vigour of populations. Yet, the positive health halo of sugar could not last. A generation later, authors of scientific papers did write about ‘The social problem growing out of the overconsumption of sugar’ and described school-based programmes 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 & 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 non-energetic beverage. After 13 years, suspicion was increasing that metabolisable 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? Although opinions on matters 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 have been scarce.

In this issue of the *British Journal of Nutrition*, 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 (approximately 430 kcal) per d gained far less weight than expected and no more weight than did women in a control group drinking zero-energy 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 randomised. I will not belabour those points here as Reid and colleagues discuss them in their article. It should also be noted that the study concerns only adult women and cannot necessarily tell us about the effects in men or children.

What does the study show?

The study’s essential finding concerns the question of compensation for liquid energy. The sucrose group gained no appreciable weight. This shows that over an extended period, at least in conditions similar to those of this study, women do compensate for additional energy 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 amount of energy consumed in the form of SSB further indicates that the vast majority of the energy consumed was compensated for. Reid *et al.* state that ‘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-analysed other studies in which adults were required to consume additional energy in SSB in randomised controlled trials (RCT), 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 Fig. 2). This indicates that, as Reid *et al.* found, over extended periods of time, the majority of the energy consumed as SSB is indeed compensated for.

Do the findings inform us about the effects of reducing sugar-sweetened beverage 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 SSB consumption on weight.

Do the findings inform us about the differential effects (if any) of consuming liquid *v.* solid energy on weight?

No. The results of Reid *et al.* only show what happens with SSB. 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 1800 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 energy is less well compensated for than is solid energy[21]. Yet, we cannot assume that individuals will not adapt to dietary changes over time. Long-term effects on weight cannot be reliably inferred from short-term effects on food intake. Indeed, to my knowledge, there are only two human RCT comparing the effects of liquid *v.* 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 analysed[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 SSB, on average, they gain some weight. What we also know from the overall literature and this new study is that, on average, adults gain far less weight than they would be expected to gain if they did not compensate. Thus, people clearly do compensate for liquid energy, although they do so incompletely. What we do not know, despite all the drama and vituperation surrounding SSB, is whether, over extended periods of time, people compensate any differently for liquid *v.* solid energy. It is high time we learned.

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