

## Invited Commentary

# Sugar-sweetened beverages, weight gain and nutritional epidemiological study design

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In this issue of the *British Journal of Nutrition*, Libuda *et al.* <sup>(1)</sup> describe their findings from the Dortmund Nutritional and Anthropometric Longitudinally Designed (DONALD) study on the relationship between sugar-sweetened beverages as well as fruit juice intake and changes in relative body weight over a 5-year period in 119 boys and 116 girls of average age 12 years at study commencement. The diet data, based on four to six 3 d weighed records, were more extensive and more carefully collected than in many studies. In boys, there was a direct association of the average age-standardised BMI with baseline fruit juice intake, not confirmed for percentage body fat or any of the data on changes in intake. This lack of association occurred in a metabolic environment of strongly increasing daily energy intake (mean 8.9 MJ increasing to 11.1 MJ over 5 years), probably corresponding to increased energy needs, although this supposition could not be directly verified as physical activity was not assessed. The boys' increase in beverage consumption was disproportionately regular soft drinks, though 100% fruit juices also increased proportionate to increased energy intake. We agree with the authors that pubertal development may have obscured any potential effect of soft drink and other energetic beverage consumption on body-weight status in boys. We expect an effect of soft drinks, all high-fructose energetic beverages, or conceivably all energetic beverages as the boys pass out of adolescence, becoming less active. The DONALD study may eventually have data to address this point.

In contrast, in girls there was an increase in age-standardised BMI and a nearly significant corresponding relationship with percentage body fat with concurrent increase in soft drinks and fruit juice (daily energy intake essentially stable, mean 7.6 MJ increasing only to 8.1 MJ over 5 years) <sup>(1)</sup>. Of interest, the girls' increase in these beverages was almost entirely 100% fruit juice. The authors note the higher social acceptance of fruit juices. Fruit juices contain nutrients besides sugar, but like soft drinks they are characterised by a high fructose content. This finding of 'change-on-change' (change in body fatness regressed on change in fruit juice) has the strong epidemiological design feature of a quasi-experimental design. While it lacks the randomisation of a true experiment, this design has in common with a clinical trial that the girls changed their fruit juice intake and the investigators then followed the body fatness outcome variable.

The authors look at the correlation of energy consumption from beverages and the rest of energy consumption to test for energy compensation, on the assumption that a zero correlation means no energy compensation, while a negative correlation means that energy compensation took place.

They found no significant cross-sectional correlation, for example, no indication of energy compensation in the individual or pooled cross-sectional surveys. However, again with the power of the quasi-experimental design, the change in the rest of energy intake was significantly inversely related to increase in energy from beverages in both boys and girls, which the authors interpreted to mean partial energy compensation <sup>(1)</sup>. We caution that the coefficient  $-0.28$  MJ per MJ of beverages may be attenuated, given that diet has substantial within-person variability <sup>(2)</sup>, even when measured with 3 d weighed food records. Furthermore, the reduction in energy intake from the rest of food may not be perfectly linearly related to the increase in energy from beverages, which is assumed in the model. Still,  $-0.28$  is substantially less than  $-1$ , which would indicate full energy compensation, and we tentatively accept that the DONALD study contributes to the evidence that the energy in soft drinks and fruit juices is only partially compensated for.

Although not the central point, nutritional researchers should take note of the statistical method used. The authors summarised their data using the powerful technique of repeated-measures regression, which, in a single statistical procedure, simultaneously compares cross-sectional and longitudinal aspects of prospective data, while properly accounting for within-person correlations. In particular the 'change-on-change' analysis is a weighted average of pair-wise differences across the four to six examinations, and so averages out random variation that would be present in any one pair, for example the comparison of the 5-year follow-up with baseline. This technique is complex to use, but has tremendous potential for sorting through the complicated data that is obtained in long-term prospective studies and in short- or long-term feeding studies.

Some limitations of the present study include the following. (1) Participants chose the first day for the dietary records, which could result in some systematic bias such as social desirability bias. (2) The sample size is small by epidemiological standards, and measurement error is most problematic in youth. (3) Confounding by other dietary factors, especially beverages, was not completely addressed. The analysis of the rest of energy focuses on energy compensation, but does not address the possibility that the beverages studied are a stand-in for other specific aspects of diet. (4) The authors' use of the term 'energetic beverages' is too comprehensive and could be misleading, in that they omitted several important energy-containing drinks, including dairy products, hot tea, coffee and alcohol. (5) The present study population has a low prevalence of overweight and obesity, so it may not be the most suitable for testing the

hypothesis that energy-rich beverages may contribute to weight gain. Indeed, the results of an experimental trial on this subject in children revealed a possible interaction between baseline weight status and the intervention, whereby the overweight children, but not the normal-weight children, tended to experience weight loss when they reduced their intake of sugar-sweetened beverages<sup>(3)</sup>.

This study has several strengths, including its prospective nature, repeated detailed dietary assessments, and novel statistical approach. The use of the residual energy intake as a means for examining energy compensation as a possible mechanism adds further novelty to the analysis.

A popular hypothesis is that energy consumed in liquid form, especially when containing a substantial amount of high-fructose maize syrup or fructose itself, may be less satiating than energy intake from solid foods, leading to passive over-consumption, with the escalating portion sizes of many sugar-sweetened beverages exacerbating this potential problem. However, the evidence on this remains inconclusive<sup>(4–6)</sup>. Specifically, the possibility has been raised that high-fructose maize syrup, used to sweeten most sugar-sweetened beverages, has unique metabolic effects with respect to obesity and diabetes risks, but any direct evidence for a unique causal role in body-weight regulation is lacking<sup>(7,8)</sup>. At least five randomised trials of sugar-sweetened beverages and body weight have been conducted in human subjects to date. Of the three trials in adults, two were of short duration and small sample size, and observed little or no evidence of effects on body weight<sup>(9,10)</sup>. One trial demonstrated a potentially important effect of a very-high-sucrose diet, primarily through sugar-sweetened beverage consumption, on changes in body weight over 10 weeks<sup>(11)</sup>. Two studies in youth provide further support of the sugar-sweetened beverages and obesity hypothesis<sup>(3,12)</sup>, although one of these studies<sup>(3)</sup> has a number of important methodological shortcomings, pointed out elsewhere<sup>(13)</sup>. As high-fructose maize syrup is nearly identical to sucrose (about 50% fructose, 50% glucose), we question the generalisability of studies demonstrating obesogenic or harmful metabolic effects of very-high-fructose diets in animals or human subjects. Indeed, the effects of sugar-sweetened beverages on postprandial glycaemia and insulinaemia are known to be very similar to other high-glycaemic-index foods and beverages<sup>(14)</sup>.

Thus the DONALD study<sup>(1)</sup>, while not conclusive, does provide evidence for the theory that at least some types of energy in liquid form, perhaps especially if fructose-based, are not fully compensated for and can lead to weight gain. This proposition may be true even for 100% fruit juice, despite the fact that it contains nutrients lacking in regular soft drinks. The study also provides a model for prospective nutritional epidemiological study design and data analysis.

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