SHORT COMMUNICATION

REPEATED EXPOSURE TO AND SUBSEQUENT CONSUMPTION OF SWEET TASTE: REANALYSIS OF TEST MEAL INTAKE DATA FOLLOWING THE REPEATED CONSUMPTION OF SWEET VS NON-SWEET BEVERAGES

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Competing Interests

In connection with research on sweet taste, KMA has received funding for research from Unilever R&D Vlaardingen, NL; has current funding from TIFN, NL (in collaboration with Arla Foods, DK; American Beverage Association, US; Cargill, US; Dutch Knowledge Centre for Sugar, NL; Firmenich, CH; International Sweeteners Association, BE; SinoSweet, China; and Unilever, NL) and from the International Sweeteners Association, BE; and has received speaker’s expenses from the International Sweeteners Association, BE; PepsiCo, US; and ILSI-North America, US.

ABSTRACT

This analysis investigated the effects of repeated exposure to sweet versus non-sweet beverages on subsequent intakes of other sweet foods, using the data published in Appleton & Blundell, Physiol Behav, 2007;92:479-486. No evidence for an increase in sweet food intakes following sweet versus non-sweet beverages was found. Some evidence was found for lower sweet food and lower sugar intakes following the consumption of sugar-sweetened beverages, but these effects may have resulted from the specific test foods used, and did not result in lower sugar intakes when sugars from the beverages and test foods were combined.

Keywords: sweet, repeated exposure, food intake, test meal intake, sugar

1. INTRODUCTION

The World Health Organization (WHO) currently recommends a global reduction in free sugar intakes for health benefits [1], and various agencies suggest that this reduction may be aided by reduced exposure to sweet taste [2,3]. The rationale is that reduced exposure to sweet taste will reduce preferences for sweetness and thus reduce the consumption of sweet-tasting foods and drinks, including sugar.

The evidence to support a relationship between sweet taste exposure and subsequent preferences or intakes, however, is limited. A recent systematic review of the published literature [4] found limited evidence for an *inverse* relationship between sweet taste exposure and preferences for other sweet foods in shorter term (<30 day) interventions, but no effects for sweet food intakes, and equivocal effects in longer term intervention and population cohort studies. However, the number of studies included in the review was small (N=21), and not all studies reported measures or data that allowed conclusions relevant to the effects of exposure to be drawn [4].

One example of such data occurred where intakes of sweet foods following sweet taste exposure were reported in combination with intakes of non-sweet foods in subsequent experimental meals and/or snacks. These data could potentially contribute to a research question on the effects of sweet taste exposure on intakes of other sweet foods, if data for sweet and non-sweet food consumption during the test meal can be separated.

This analysis sought to separate the data on sweet and non-sweet food consumption in five test meals and snack periods following repeated exposure to sweet versus non-sweet beverages, as published by Appleton & Blundell in 2007 [5].

2. METHODS

The original data were collected for a study investigating the effects of sweet taste and energy on short-term appetite in habitual high and low consumers of artificially-sweetened beverages [5]. Briefly, using a within-subjects design, 20 female habitual high (N=10) and habitual low (N=10) consumers of artificially-sweetened beverages consumed four portions of two sweet or one non-sweet beverage over the course of a day, and intake both during and at the end of the day were assessed through the measured consumption of sweet and non-sweet food items. The sweet beverages involved in the study were a sweet/low energy beverage sweetened with aspartame and acesulfame-K (AS) (21kJ, 0g sugar/330ml) and a sweet/high-energy beverage sweetened with sucrose (NS) (523kJ, 27g sugar/330ml), and the non-sweet beverage was water (W) (0kJ, 0g sugar/330ml). All beverages were provided in four portions of 330ml to allow high exposure to the taste and energy content of the beverages, and were consumed in full at 10am, 11:30am, 2pm, and 3:30pm.

Effects of the beverage exposure were assessed during exposure through measurement of snack consumption during the same morning or afternoon period, and after exposure in a test meal at lunch, a test meal in the evening and during the rest of the evening period. Morning and afternoon snackboxes were composed of 3 non-sweet foods: 3 x 30 g packets of *Walkers* crisps, *Jacobs* Mini Cheddar cheese biscuits, and *TUC* cheese sandwich biscuits; and 3 sweet foods: 3 x 30g packets of *McVities* mini chocolate digestive biscuits, *Maryland* chocolate chip cookies and *McVities* plain sweet digestive biscuits. The lunch meal was composed of 4 non-sweet foods: cream cheese or turkey sandwiches, dependent on personal preference (*Mighty White* bread + *Philadelphia* cream cheese or *Bernard Matthews* wafer thin turkey slices), *Safeway* Healthy Living coleslaw, Iceberg lettuce, *Safeway* cheese and tomato pizza; and 3 sweet foods: *Bassetts* Jelly Babies, *Safeway* Marshmallows, and *Müller* Light strawberry yoghurt. The evening dinner meal was composed of 2 non-sweet foods: *Safeway* vegetable lasagne and *Safeway* frozen peas; and 2 sweet foods: *McVities* chocolate digestive biscuits and Granny Smith apples. The evening snackbox was composed of 5 non-sweet foods: *Safeway* bread rolls (consumed alone, or with individual portions of margarine and/or cheese), individual packets of *Walkers* crisps, and *Jacobs* Mini Cheddar cheese biscuits; and 5 sweet foods: bread rolls consumed with (margarine and) jam, individual packets of *McVities* mini chocolate digestive biscuits, and *Maryland* chocolate chip cookies, *Safeway* yoghurts and Granny Smith apples. All foods are commonly consumed in the UK. None of the sweet foods in the test meals / snack periods were foods that were used for the exposure manipulation. Participants were not allowed to consume any other foods or fluids throughout the day except in the evening, where nonalcoholic beverages (e.g. tea, coffee) could also be consumed and were recorded.

Food intake in all test meals / snack periods was measured by weight and converted into energy consumed using manufacturers' information and food composition tables. Original manufacturer information was no longer available to conduct this reanalysis, thus current manufacturer information was used. Taste (sweet/non-sweet) data on evening beverage consumption were also not available, so evening beverage consumption was not considered. To address the research question, percent weight and energy consumed from sweet foods, sugars and percent energy consumed from sugars were calculated. These calculations were made for each test meal / snack period individually and added cumulatively across the day. Analyses were conducted twice – firstly comparing the two low-energy beverages: sweet (AS) and non-sweet (W), and secondly, comparing the high-energy sweet (NS) and the non-sweet beverage (W). Analyses on sugar consumption were also conducted for cumulative measures across the day comparing the high-energy sweet (NS) and non-sweet beverage to include the sugar contained in the high-energy sweet beverage. Finally, due to high standard deviations in the data set and the resulting possibility that effects may be masked, number of individuals demonstrating an increase in sweet food intake following sweet compared to non-sweet beverage exposure were compared using Chi-squared statistics. All participants provided complete data sets. Consumer type, as required for the original study, was not considered in the re-analysis, as these consumer types were not defined by taste exposure. Analyses were conducted in IBM SPSS. Significance was set at $p<0.05$.

3. RESULTS

In individual test meals and snack periods, no differences between exposure to sweet (AS or NS) vs non-sweet (W) beverages were found in any measure during the morning snack period (largest $t(19)=1.54$, $p=0.14$), at lunch (largest $t(19)=1.20$, $p=0.24$), during the afternoon snack period (largest $t(19)=1.26$, $p=0.22$), or at dinner (largest $t(19)=1.49$, $p=0.15$). In evening snack intake, differences were found between exposure to NS vs W beverages in all percent measures (smallest $t(19)=2.16$, $p=0.04$), with a similar trend in sugar intakes ($t(19)=2.04$, $p=0.06$). Percent weight and energy consumed from sweet foods, sugars and percent energy consumed from sugars were lower following the NS compared to W beverages. No effects were found for exposure to AS vs W beverages (largest $t(19)=1.26$, $p=0.22$). Mean (± SD) values for evening snack intake are provided in Table 1.

Cumulative intakes of sweet foods and sugars are also given in Table 1. No differences between exposure to sweet (AS or NS) vs non-sweet (W) beverages were found in any measure of cumulative intake up to and including lunch (largest $t(19)=1.21$, $p=0.24$), up to and including afternoon snacks (largest $t(19)=2.03$, $p=0.06$), or up to and including dinner (largest $t(19)=1.96$, $p=0.06$). Across the whole day, differences were found between exposure to NS vs W beverages in percent energy consumed from sweet foods ($t(19)=2.63$, $p=0.02$) and sugar intakes ($t(19)=2.82$, $p=0.01$). Percent energy consumed from sweet foods and sugar intakes were lower following the NS compared to the W beverages. No other effects were found (largest $t(19)=1.95$, $p=0.07$). Following effects in sugar intakes, the sugars provided in the NS beverage were also added to cumulative intakes. Higher sugar intakes during NS vs W consumption were found at all time points (smallest $t(19)=6.21$, $p<0.01$). Compensation for the sugars provided by the beverages ranged between 3.4 ± 14.8% during the morning snack period to 19.0 ± 30.2% across the whole day.

Table 1 about here

Number of individuals demonstrating an increase in sweet food intake following sweet taste exposure compared to non-sweet taste exposure is given in Table 2. More individuals consumed a lower percent energy from sweet foods over the whole day, and lower sugars up to and including lunch, dinner and over the whole day following exposure to the NS compared to the W beverage (smallest $\chi^2(1)=5.0$, $p<0.05$).

Table 2 about here

4. DISCUSSION

This analysis investigated the effects of repeated exposure to sweet versus non-sweet beverages on subsequent intakes of other sweet foods. No effects were found following exposure to low-energy sweet beverages. Exposure to high-energy sweet beverages resulted in a lower percent weight and percent energy consumed from sweet foods and a lower percent energy consumed from sugars in the evening, a lower percent energy consumed from sweet foods and lower sugar intakes cumulatively over the whole day, and more individuals consumed lower percent energy from sweet foods and sugar intakes over the whole day following the high-energy sweet compared to the non-sweet beverages.

These findings do not demonstrate a positive association between sweet taste exposure and sweet taste intakes. Similar findings were reported in the recent systematic review, where no effects were found in four short term intervention studies where intakes of other sweet foods were investigated [4], and are reported in two further short-term intervention studies that have since been published [6,7]. The findings of longer term intervention studies also typically show no changes to the intakes of other sweet foods [8-10], although some studies report some decreased consumption of select sweet foods following sweet taste exposure compared to control [9,10], as was also found here.

The findings demonstrate a reduced consumption of sugars and energy from sweet foods following consumption of sugar-sweetened beverages. These findings may suggest some degree of nutrient regulation where earlier consumption of sugars results in reduced subsequent voluntary consumption of sugars [11], but caution is required considering the limited test foods presented. Sugar consumption resulted in reduced sugar consumption, but all sweet test foods in this study were high in sugar content, thus it is not clear if this was an attempt to balance sugar consumption or an attempt to balance sweet taste consumption that necessitated reduced sugar consumption due to the use of sugar-sweetened sweet test foods. Investigation of the impacts of sugar-sweetened food consumption on subsequent voluntary sweet food consumption using a range of sweet foods with high and low sugar and energy content would tease apart effects due to nutrient or sensory qualities.

Compensation for the stipulated sugar consumption is low, but good compensation was not possible. Each NS beverage portion provided 27g sugars, providing 108g sugars over the whole day, and mean sugar consumption from all test foods (sweet and non-sweet) in W, AS and NS conditions was 134 ± 72g, 132 ± 67g, and 114 ± 56g, respectively. To reduce sugar consumption from the test meals and snacks in this study by 108g would have required a substantial reduction in food intake. Tordoff and Alleva [12] also report reduced consumption of sugars from foods following three weeks exposure to sugar-sweetened beverages, with incomplete compensation. However, Mattes [13] reports no reduction in energy consumed from sweet foods following repeated consumption of a sucrose-sweetened breakfast compared to plain, and Carroll et al [6] report no compensation for the sugar consumed at a sugar-sweetened breakfast compared to a plain breakfast over three weeks. Studies where participants are asked to replace sugar-sweetened beverages/foods with non-sweet beverages/foods also report no increase in sugar consumption from other foods [9], but few studies have investigated a possible compensatory effect specifically for sugar [10,14]. This compensation for previous sugar consumption should not be confused with compensation for previous energy intake. Repeated studies suggest poor compensation for the energy consumed in sugar-sweetened beverages [10,14], but energy intake is explicitly not the topic of this article, and differences between energy intake and sugar intake are clearly demonstrated.

The potential of this reanalysis is compromised by the specific sweet and non-sweet foods provided. The test meal foods were selected based on their usual consumption by UK consumers and acceptance as component parts of a lunch and evening meal, but they differ not only in taste, but also in a number of other factors such as texture, perceived healthiness, or position in a meal as first or second course, and these factors may have determined their consumption to a greater extent than taste. The sweet and non-sweet morning and afternoon snacks were comparable in texture, healthiness, and intended use, and no effects of sweet taste exposure were found here, but in studies that are specifically designed to assess sweet food consumption, good control of these food characteristics is required.

In conclusion, this analysis sought to investigate the effects of repeated exposure to sweet versus non-sweet beverages on subsequent intakes of other sweet foods, in order to contribute further evidence to a research question regarding the impacts of sweet taste exposure on sweet food intakes. No evidence for an increase in sweet food intakes following the repeated consumption of sweet beverages was found. Some evidence was found for a reduction in sweet food and sugar intakes following the consumption of sugar-sweetened beverages, but this may have resulted from the specific test foods used, and did not result in a lower sugar intake when the sugar from the sweet beverages and test foods were added together.

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Table 1: Mean (± SD) values for percent weight consumed from sweet foods, percent energy consumed from sweet foods, sugars consumed and percent energy consumed from sugars, after W, AS and NS beverages cumulatively up to and including lunch, up to and including dinner, in evening snack intake and cumulatively over the whole day (N=20).

	Non-sweet (W)	Sweet Low-energy (AS)	Sweet High-energy (NS)
Percent weight from sweet foods (%)			
Up to and including lunch	40.5 (21.8)	44.7 (17.5)	40.9 (22.5)
Up to and including dinner	25.5 (13.4)	27.2 (11.3)	25.0 (13.7)
Evening snack intake	58.3 (35.6)[a]	51.3 (31.5)	36.4 (31.1)[a]
Over the whole day	29.5 (11.4)	29.5 (11.3)	27.2 (12.3)
Percent energy from sweet foods (%)			
Up to and including lunch	36.6 (20.4)	35.7 (17.9)	36.1 (20.9)
Up to and including dinner	33.9 (12.8)	32.5 (13.3)	30.9 (16.4)
Evening snack intake	55.0 (35.2)[a]	46.0 (32.8)	30.4 (27.4)[a]
Over the whole day	37.6 (13.3)[a]	34.2 (15.0)	31.6 (15.1)[a]
Sugars (gram.)			
Up to and including lunch	79.7 (62.0)	77.6 (54.0)	71.1 (46.6)
Up to and including dinner	118.0 (69.2)	116.2 (62.3)	104.0 (55.5)
Evening snack intake	16.2 (11.9)	15.6 (8.3)	9.7 (8.2)
Over the whole day	134.2 (72.1)[a]	131.8 (66.9)	113.7 (56.0)[a]
Percent energy from sugars (%)			
Up to and including lunch	25.8 (12.4)	25.2 (11.3)	26.4 (12.9)
Up to and including dinner	21.7 (6.9)	20.5 (5.8)	21.6 (7.8)
Evening snack intake	13.0 (7.7)[a]	12.5 (7.7)	7.9 (6.6)[a]
Over the whole day	20.0 (6.3)	18.6 (5.5)	19.2 (6.8)

[a] Significant differences between W and NS beverages.

Table 2: Number (percentage of 20) of individuals who consumed a higher percent weight from sweet foods, a higher percent energy from sweet foods, more sugars and a higher percent energy from sugars, after AS and NS beverages compared to W beverages up to and including lunch, up to and including dinner and over the whole day (N=20).

	Up to and including lunch	Up to and including dinner	Over the whole day
After Sweet Low-energy (AS)			
Percent weight from sweet foods	12 (60%)	12 (60%)	9 (45%)
Percent energy from sweet foods	12 (60%)	7 (35%)	10 (50%)
Sugars	11 (55%)	10 (50%)	8 (40%)
Percent energy from sugars	12 (60%)	6 (30%)	8 (40%)
After Sweet High-energy (NS)			
Percent weight from sweet foods	9 (45%)	8 (40%)	6 (30%)
Percent energy from sweet foods	8 (40%)	7 (35%)	5 (75%)[a]
Sugars	4 (20%)[a]	4 (20%)[a]	3 (15%)[a]
Percent energy from sugars	9 (45%)	8 (40%)	9 (45%)

[a] Significantly different from a null hypothesis of no effect