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Manipulating fat content of familiar foods at test-meals does not affect intake and liking of these foods among children☆

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Abstract

We investigated effects of manipulating fat content of familiar foods at two test-meals in 74, 4–6-year-old children. Liking, energy intake, and weight-based food intake were assessed for a meal consisting of macaroni and cheese, pudding, chocolate milk and regular milk in high-fat and low-fat versions. Liking ratings and consumption by weight did not differ between versions, but energy intake was 59% greater with the high-fat version. We conclude that manipulating fat content had little effect on liking and weight-based food intake, but markedly influenced overall energy intake, and thus might provide a means of lowering children's energy consumption.

Keywords

Fat preference; Energy density; Energy intake; Food intake; Liking; Children

Introduction

Taste preferences are the most important factors driving food selection and intake in children (Birch, 1999). However, few studies have examined how children's taste preferences for fat relate to fat intake and obesity (Fisher & Birch, 1995; Ricketts, 1997). Understanding this relationship is important because fat consumption among children in the United States is above recommended levels (Munoz, Krebs-Smith, Ballard-Barbash, & Cleveland, 1997). This is a concern because high-fat diets are associated with increased energy intake (Donahoo et al., 2008), obesity, and related chronic diseases (Lee, 2007).

Studies with adults suggest that humans eat fixed amounts of food (i.e. a constant weight or volume), regardless of its energy density (Bell & Rolls, 2001; Stubbs, Ritz, Coward, &

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Prentice, 1995). This suggests that lowering energy density could be a strategy for reducing energy intake in the diet. Few studies have investigated this phenomenon in children and findings from these studies are ambiguous. In both laboratory settings of 3–7-year olds (Faith et al., 2004) and free-living environments of 3–6-year olds (Kral et al., 2007), children compensate for reductions in energy density. However, as demonstrated in similar age groups, the compensation is incomplete (Birch, Johnson, Jones, & Peters, 1993; Cecil et al., 2005), and may be affected by other factors, such as serving size (Fisher, Liu, Birch, & Rolls, 2007). Thus overall, reducing energy density has been associated with reduced energy intake in children both within meals (Leahy, Birch, & Rolls, 2008a) and over successive meals (Leahy, Birch, & Rolls, 2008b). Further, cross-sectional data in children suggest positive associations between energy density and total energy intake (Mendoza, Drewnowski, Cheadle, & Christakis, 2006). It should be noted, though, that the long-term effects are unclear. Some studies find no effects (Kring & Heitmann, 2008), while others demonstrate positive associations between energy density of the diet and adiposity (Johnson, Mander, Jones, Emmett, & Jebb, 2008). Discrepant findings might be due to age differences among study cohorts, as compensation ability has been reported to decline with age (Cecil et al., 2005).

Fat is the most energy-dense macronutrient, thus one obvious way to reduce energy density is to reduce fat content of foods. However, manipulating nutrient composition and energy density of foods can reduce their palatability and acceptance, but this is influenced by the target food in question (Kähkönen & Tuorila, 1999; Mela & Sacchetti, 1991), the nutrients that are manipulated (Drewnowski, Nordensten, & Dwyer, 1998), and the extent to which the manipulation varies from the usual version (Swanson, Perry, & Carden, 2002). According to Rapp and colleagues, regular (full-fat) versions of foods are preferred over low fat alternatives (Rapp et al., 2009). Due to the close link between preferences and intake (Birch, 1999), reduced acceptance could result in reduced intake, and for some foods, this could be a serious obstacle to overcome. Thus, in the present study, we hypothesized that reducing fat content of familiar foods would decrease their acceptance and intake among children.

The objective of the present study was to determine whether children's *ad libitum* intake and liking of familiar foods differ when the fat content and energy density of these foods is manipulated.

Materials and methods

Participants

Participants were 74 children, 29 males (39%) and 45 females (61%), aged 4–6 years (mean age 5.6 ± 0.8 years (SD)) from diverse ethnic backgrounds. Parents described their children's race/ethnicity as African-American/Black (41.9%), Asian (2.7%), Caucasian (10.8%), Hispanic/Latino (33.8%), or other (10.8%), which typically signified mixed racial identity. Families were recruited by posting flyers on a popular internet website, as well as in and around the hospital community where the study was performed. Parents gave informed, written consent, and children agreed to participate. Parents were modestly compensated for time and travel, and children received a small prize after each visit. The study complied with the Helsinki declaration and was approved by the Institutional Review Board of St. Luke's-Roosevelt Hospital.

Anthropometric measures were performed by a trained researcher. Children were weighed and measured in stocking feet and light clothing on a standard balance scale and stadiometer, respectively. Height and weight were converted to body mass index (BMI = kg/m^2), and percent BMI and BMI *z*-scores were calculated using the CDC growth charts conversion program. On average, children had a mean BMI *z*-score of 0.98 ± 0.95, which corresponds to slightly under the 85th BMI-for-age percentile.

Study design

Children attended a total of four dinner visits, two of which will be described here, as part of a larger study to understand the factors that impact early taste preferences (data reported elsewhere). Visits were conducted at the Child Taste and Eating Laboratory at St. Luke's Hospital. Participants arrived between 4:00 and 6:00 pm, which is a usual dinner time for children, and visits lasted ~1 h (including some playtime prior to the meal to familiarize children with the surroundings and research staff).

Ad libitum meals

At both dinner visits, meals consisted of macaroni and cheese, pudding, milk, and chocolate milk, chosen because they are familiar and well-liked by this age group (Sud, Tamayo, Faith, & Keller, 2010). Standard portion sizes of each food item are indicated in Table 1 and were selected from the Continuing Survey of Food Intake by Individuals (CSFII) (Smiciklas-Wright, Mitchell, Mickle, Cook, & Goldman, 2002). Foods were provided on serving trays, with main entrées served on plates. All foods were served simultaneously, using the same presentation across meals, and children were free to select their preferred order of food items including going back and forth between items. Children were allowed ~30 min to eat *ad libitum*, with additional, identical sized portions offered for any item a child finished. Throughout the meal, a child was accompanied by a given researcher while the parents were waiting nearby (but outside the child's vision). Although the goal was to have the same researcher accompany the child through all visits of the study, due to scheduling conflicts this was not always possible. While the child ate, the researcher read a non-food related story to serve as a neutral distraction. Pre- and post-weights of each food item were measured to assess intake.

Children received the meal items in high-fat (HF) versions at one session, and low-fat (LF) versions at the other session, based on a randomly assigned order that was balanced across subjects. In the HF meal, 34–48% of calories were from fat, and in the LF meal, 0–11% of calories were from fat. Fat contents of the foods were designed to produce maximal differences between versions without altering other taste and/or flavour attributes of the foods. Also, foods were selected to be lower (low-fat) or higher (high-fat) than the "regular" version of the product sold on the market. Recipes for the low- and high-fat macaroni and cheese entrées were adopted from those used in a previous study (Tepper & Farkas, 1994). Exact recipes can be obtained from the authors upon request. Energy densities and macronutrient compositions are shown in Table 1. Volumes of the foods were not measured, but weights and serving containers were the same for the HF and LF versions.

In order to match the pudding textures, a small amount of carrageenan (Viscarin SD 389, FMC Corp., Philadelphia, PA) was added to the LF version as a thickener. For the macaroni and cheese, a commercially available, non-fat butter flavoring was added to the LF version (Butter Buds, Cumberland Packing Corp., Brooklyn, NY). Nothing was added to the milk samples.

Liking ratings

Prior to each meal, children were served ~10 g samples of each food item in 2 ounce soufflé cups. They were asked to taste each food/beverage and rate liking in a monadic manner on a 5-point facial hedonic scale with the categories “super bad”, “bad”, “maybe good or maybe bad”, “good”, and “super good” (Chen, Resurreccion, & Paguio, 1996). A brief training procedure was used before children rated the foods in order to ensure they understood how to use the scale. The training consisted of first explaining the meaning of each face, and then asking the child to name some examples based on their own preferences for the various categories. If it seemed difficult for a child, or they miscategorised their own examples, the training procedure was repeated until the child understood the scale. In previous studies with this age group, test–retest reliability scores for this scale are high (Spearman’s rho = 0.91) (Keller, unpublished data). Between samples, children rinsed their mouths with spring water.

Data analyses

Descriptive statistics were used to calculate means, standard deviations, and frequencies. Pearson’s correlation coefficients were used to determine the within-child associations between primary outcome variables (liking and intake at HF and LF meals). Because child age was positively associated with intake of several of the meal items, partial correlation coefficients were calculated, after adjusting for child age, to determine the relationship between intake at HF and LF meals independent of age differences. Liking and intake (both energy and weight-based) were also compared across HF and LF meals using 2-tailed paired samples *t*-tests. The significance level was set to 5%, and analyses were performed in PASW 18.0 (SPSS Inc., Chicago, IL, USA).

Results

Energy intake

Intakes for total energy and each individual food item at the HF and LF meals were highly correlated to one another ($p < 0.001$), except for milk, which was modestly correlated ($p < 0.05$), see Table 2. As the LF and HF food items differed in energy density, there were robust significant differences in energy intake at the two meals, as intakes at HF meal exceeded those at the LF meal ($p < 0.001$), except for milk, which did not differ between meals. In fact, the total average energy intake was 59% higher at the HF meal compared to the LF meal, which is equivalent to an additional 184 kcal (768 kJ) consumed at the HF meal.

Food intake (weight-based)

Children consumed similar weight-based amounts of food at the HF and LF meals for all food items except pudding, where children ate significantly more of the HF version (49 g) compared to the LF version (37 g) ($p < 0.05$) see Table 2.

Liking

Liking scores did not differ as a function of fat content for any of the food items (p-values from 0.13 to 0.80), see Table 3.

Discussion

Energy intake

Manipulating fat content and energy density in familiar foods served at test-meals substantially affected children's energy intake. An average increase in energy intake of 59% (or 184 kcal/768 kJ) at the HF meals compared to the LF meals is a sizeable difference that can have dramatic long-term effects if not compensated for by decreased intake at subsequent meals or increased activity levels. The difference is comparable to findings in adults showing 52% higher energy intake on diets that are high vs low in energy density (Duncan, Bacon, & Weinsier, 1983). Conversely, these findings also suggest that lowering fat content and energy density in familiar foods might provide a promising means for lowering energy intake in children.

Evidence for caloric compensation is much clearer in children than adults (Birch & Deysher, 1986). In general, children tend to vary substantially in their energy intake between meals, whereas total daily energy intake is rather stable (Birch, Johnson, Andresen, Peters, & Schulte, 1991). It is therefore possible that children in our study compensated for the high energy intake at the HF meal and low energy intake at the LF meal during the following day. However, previous studies show that children's energy compensation is incomplete. For example, when Birch et al. (1993) reduced energy density, 2–5-year-old children compensated, but not completely; there was still a difference of 23.9 kcal (100 kJ) between conditions over a 2-day period. Leahy et al. (2008b) reduced energy density among 3–5-year-old children and observed no compensation, so energy intake differed by 389 kcal (1628 kJ) over a 2-day period. These differences are smaller than the differences in energy intake observed in the present study, but over time minor imbalances in energy intake (as low as 2%), can have cumulative effects and eventually lead to obesity (Goran, 2001). It should be remembered, though, that children need to maintain a positive energy balance in order to ensure healthy growth, and attempts to lower fat and energy content in their diets should only be considered when appropriate (e.g. weight reduction).

Food intake (weight-based)

Children consumed similar weight-based amounts of HF and LF foods – as was observed in adults (Stubbs et al., 1995; Bell & Rolls, 2001). Similar weight-based intake across different energy densities has also been shown in studies with children (Fisher et al., 2007; Leahy et al., 2008b; Bouhlal, Issanchou, & Nicklaus, 2011). This suggests that reducing fat content might lower children's total dietary energy intake, as was found in adult cohorts (Donahoo et al., 2008). However, long-term effects of energy density reductions need to be further examined, in both adults and children.

The similar intake of LF and HF foods is also in accordance with expectations. Children's preferences are strong predictors of their intake (Birch, 1999), and because liking measures for HF and LF foods did not differ, no differences in intake would be expected. In fact, the only difference observed in intake was for pudding; intake was highest for the HF version. As full-fat versions of foods have been shown to have higher acceptability than reduced fat versions (Rapp et al., 2009), this could reflect a small difference in acceptance between the two versions for which intake was a more sensitive measure than liking. It is possible that the liking scale used was not sensitive enough to detect these small changes. This is elaborated below. Moreover, because carrageenan was added to thicken the low-fat version, we cannot rule out the possibility that children consumed more of the high-fat version because they disliked this thickener.

Liking

Liking scores for the HF and LF foods and milks did not differ significantly from one another. From a health perspective this is a positive finding because it suggests that reducing fat content of familiar foods in children can be accomplished without inducing large changes in their acceptance of these foods. Findings in adults show that it is possible to prepare foods of similar acceptance when energy density is manipulated (Stubbs et al., 1995). Similar preference ratings of high and low energy density foods and beverages were also observed among 2–5-year-old children (Leahy et al., 2008a, 2008b). However, in the current study, all of the included foods and beverages were well-liked; all liking scores are around 4 (corresponding to "good"), and this could partly explain the fact that when fat content was changed, liking ratings remained high. It is possible that more pronounced differences between HF and LF versions would be observed if we used food items that are not as familiar and/or well-liked by children (e.g. cream soups, yogurts, or salad dressings), but additional research is needed to confirm this.

Furthermore, it is possible that the 5-point category scale was not sensitive enough to detect differences among our included food items. However, due to the close link between preferences and intake in children (Birch, 1999), this is unlikely, as we did not see consistent differences in intake either. It should be noted, though, that preferences for the LF and HF versions were measured at two different sessions, and direct comparison at the same session might have produced different results. Forced choice tasks have previously revealed differences in acceptance between products among 10-year-old children that were not revealed by category scales (Engell, Bordi, Borja, Lambert, & Rolls, 1998). Thus, follow-up investigations might wish to use rank order preference tests to determine if children prefer HF versions to LF versions when given in the same test setting. However, because children are generally not served several versions of the same food at the same meal, the current findings may be more applicable to real-world eating situations.

Limitations

The sample was highly heterogenous with regards to ethnicity, and from a metropolitan area. It is unknown if results can be extrapolated to different samples. Our aim was to compare liking and intake between LF and HF meals, and we did not collect data on appetite status prior to the meal, or energy intake the subsequent day (although all children were reportedly 3-h fasted when reporting to the study). Collection of these data is necessary to investigate possible compensation effects, as well as gain a better understanding of the mechanisms by which lowering fat content may lead to reductions in energy intake. Finally, testing was carried out in a laboratory, and although surroundings were designed to be child-friendly, different results might be attained in a home-setting.

In conclusion, manipulating fat content in familiar foods served at *ad libitum* meals had little effect on liking and absolute weight-based food intake, but markedly influenced overall energy intake. In the high-fat meal, children consumed almost 60% more calories. We speculate that children's intake may be driven by specific types of foods, and the weight (or volume) of amount eaten, as opposed to energy density and energy intake. However, more research with other age groups and types of foods is needed to strengthen these claims.

Clinical application

If these findings are replicated and tested over a longer time period, manipulating fat content of well-liked, familiar foods could be a way of reducing young children's energy intake and become part of a strategy for preventing obesity. Manipulating fat content is easily done for most dishes, and can be done by both parents and the food industry.

It should be emphasized that the differences in fat content between the HF and LF versions were large in this study, but to increase children's acceptance and the likelihood of succeeding, it might be preferable to gradually reduce the fat content of a familiar and well-liked food, as opposed to changing recipes dramatically.

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Table 1

Energy density and macronutrient composition of test foods, and for comparison, values for typical, regular (unmodified) versions of these foods (not included in the study).

	Energy density (kcal/g)	Serving size (gram per portion)	Fat		Carbohydrate		Protein	
			wt.%[c]	E%[d]	wt.%[c]	E%[d]	wt.%[c]	E%[d]
Low fat (LF) foods								
Macaroni and cheese	1.78	133 ± 3	2.2	11	33.4	75	6.2	14
Pudding	0.88	100 ± 3	0	0	19.4	88	2.6	12
Milk	0.33	150 ± 3	0	0	5.0	60	3.3	40
Chocolate milk	0.54	150 ± 3	0	0	10.3	76	3.0	24
High fat (HF) foods								
Macaroni and cheese	2.68	133 ± 3	13.1	44	26.1	39	11.4	17
Pudding	1.47	100 ± 3	5.7	35	20.9	57	2.9	8
Milk	0.63	150 ± 3	3.4	48	5.0	31	3.3	21
Chocolate milk	0.82	150 ± 3	3.3	36	10.0	49	3.1	15
"Regular" versions[a]								
Macaroni and cheese	2.20	130	4.2	17	38.5	70	7.2	13
Pudding	0.97	113	1.3	12	20.4	84	1.0	4
Milk[b]	0.54	240	2.1	35	5.4	40	3.4	25
Chocolate milk[b]	0.75	240	1.3	15	12.6	67	3.4	18

[a] Data on regular food versions was taken from the leading market brand for each of these food items.

[b] For milks, values are included for 2% fat versions.

[c] Specifies percentage of macronutrient by weight of food.

[d] Specifies percentage of macronutrient by energy.

Table 2

Mean values (± SD) for energy intake, and weight-based food intake of high-fat (HF) and low-fat (LF) food items, as well as Pearson's partial correlation coefficients adjusted for child age, and paired sample *t*-tests between them, $n = 74$ for all food items.

Food and energy intake	Weight-based food intake			Energy-based food intake			Partial correlation coefficient[d]
	HF food intake (g)	LF food intake (g)	Paired *t*-test[a]; *t*	HF food (kcal)	LF food (kcal)	Paired *t*-test[a]; *t*	
Macaroni and cheese	105 ± 94	98 ± 93	NS	281 ± 252	176 ± 165	5.13**	0.70**
Pudding	49 ± 72	37 ± 51	2.13*	72 ± 105	33 ± 45	4.33**	0.74**
Milk	30 ± 52	44 ± 78	NS	19 ± 33	14 ± 26	NS	0.30*
Chocolate milk	149 ± 135	162 ± 145	NS	122 ± 110	87 ± 78	3.87**	0.70**
Total for foods[b]	154 ± 127	136 ± 114	NS	353 ± 288	209 ± 179	6.11**	0.77**
Total for beverages[c]	179 ± 157	206 ± 170	NS	140 ± 123	101 ± 84	3.56**	0.61**
Total for all items	333 ± 228	342 ± 234	NS	493 ± 338	310 ± 224	7.63**	0.70**

NS: not significant.

[a]For all *t*-tests, df = 73.

[b]Foods are comprised of macaroni and cheese, and pudding.

[c]Beverages are comprised of milk, and chocolate milk.

[d]As the weight-based food intake is proportional to the energy-based food intake, this coefficient is the same for both.

* $p \leq 0.05$.

** $p \leq 0.001$.

Table 3

Mean values (±SD) for liking (assessed on a 5-point facial hedonic scale) of high-fat (HF) and low-fat (LF) food items, as well as Pearson's correlation coefficients, and paired sample *t*-tests between them.

Liking	n^a	HF liking	LF liking	Paired *t*-test[b]; *t*	Correlation coefficient[c]
Macaroni and cheese	68 (71/69)	4.0 ± 1.4	3.8 ± 1.4	NS	0.44[*]
Pudding	67 (71/68)	3.9 ± 1.4	3.9 ± 1.4	NS	0.49[*]
Milk	69 (71/70)	3.7 ± 1.5	3.8 ± 1.3	NS	0.56[*]
Chocolate milk	69 (71/70)	4.2 ± 1.3	4.1 ± 1.3	NS	0.60[*]

NS: not significant.

[a]Designates number of children with both HF and LF ratings. Missing data in the liking ratings due to refusal of some children to taste and rate foods. First number in bracket specifies children rating the HF version, while the second number specifies children rating the LF version.

[b]For *t*-tests, df = 66–68.

[c]Not adjusted for age, as age did not influence the models.

[*]$p \leq 0.001$.