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Caloric compensation in preschool children: Relationships with body mass and differences by food category

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ABSTRACT

Maintaining a healthy weight may involve compensating for previously consumed calories at subsequent meals. To test whether heavier children demonstrated poorer caloric compensation across a range of conditions, and to explore whether compensation failure was the result of inadequate adjustment of overall intake or specific over-consumption of highly palatable, high energy-density 'junk' foods, we administered two compensation tests to a sample of 4–5 y olds. For Test A, preloads varied only in carbohydrate content and were organoleptically indistinguishable (200 ml orange-flavored beverage [0 kcal vs. 200 kcal]). For Test B, the preloads varied substantially in both macronutrient composition and learned gustatory cues to caloric content (200 ml water [0 kcal] vs. 200 ml strawberry milkshake [200 kcal]). Each preload was followed 30 min later by a multi-item ad-libitum meal containing junk foods (chocolate cookies, cheese-flavored crackers) and core foods (fruits and vegetables, bread rolls, protein foods). Testing took place at the children's own school under normal lunch-time conditions. Children were weighed and measured. Caloric compensation occurred in both tests, in terms of total, junk and core food intake (RMANOVA, all $p < 0.01$). Higher BMI z scores were associated with greater average caloric compensation ($r = -0.26$; $p < 0.05$), such that overweight/obese children showed least compensation (41%), children over the 50th centile the next least (59%), and children under the 50th centile (80%) the most. For Test A only, obese/overweight children compensated less well than normal-weight children in terms of junk food intake (RMANOVA preload-by-weight group interaction $p < 0.05$), with no significant effect for core foods. Our results suggest that caloric compensation is consistently poorer in heavier children, and that overweight/obese children's preferences for junk foods may overwhelm intake regulation mechanisms within meals containing those foods.

1. Introduction

A continual process of caloric compensation, i.e. the regulation of energy intake by adjusting one's intake based on previous consumption, may be required for maintaining energy balance and remaining at a healthy body weight. This process could be entirely subconscious and therefore amenable to measurement in young children, who are less likely than adults to exert conscious control over their food intake. Several early and influential papers have argued that the ability to compensate is naturally present in the majority of infants and young children when given a nutritionally balanced set of foods (Fomon, 1993; Davis, 1928, 1939), and data from laboratory tests (Birch & Deysher, 1986), controlled feeding studies (Birch, Johnson, Andresen, Peters, & Schulte, 1991) and 24-h dietary recalls (Shea, Stein, Basch, Contento, & Zybert, 1992) have provided some degree of support.

If compensation ability differs between individuals and influences body weight, we would expect heavier children to exhibit poorer compensation ability. This has important implications, since failure to compensate beginning in childhood could have a large cumulative effect on weight over the lifetime. Caloric compensation is most commonly tested in the laboratory using a preloading paradigm, in which ad libitum intake is assessed following a higher-

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energy or lower-energy preload, within a repeated-measures design, and the degree of compensation for the difference in preload intake is calculated, typically using the following equation: COMPX = ((lunch calories after low energy preload - lunch calories after high energy preload)/(high energy preload calories - low energy preload calories)) x 100 (Johnson & Birch, 1994). Using this method in a sample of preschool children, (Johnson and Birch 1994) assessed compensation for high-energy (150 kcal) vs. low-energy (3 kcal) juice preloads, similar in flavor and appearance, at an ad libitum multi-item lunch (turkey hot dogs, cheese slices, applesauce, carrots, fig newtons and 2% milk) consumed 20 min afterwards. Mean COMPX was 46.2 ± 5.7%, with a range of −80% to 230%, and there was a significant negative association (r = -0.37) between compensation and adiposity in girls only, such that poorer compensation was associated with greater sub-scapular skinfolds and relative weight-for-height. Associations with adiposity have been observed in older children (Bellissimo et al., 2008) and adults (Fricker, Chapelot, Pasquet, Rozen, & Apfelbaum, 1995; Speechly & Buffenstein, 2000) too.

However, in parallel with the positive findings reported above, it should be noted that many studies have failed to find associations with child adiposity. Using a similar paradigm to that described in Johnson and Birch (1994), in which 3–7 y old sibling pairs were given a high (150 kcal) or low (3 kcal) calorie fruit drink preload, and then provided with a multi-item meal (macaroni and cheese, canned string beans, string cheese, graham crackers, green grapes, baby carrots and whole milk; 800 kcal) 25 min later, (Faith et al. 2004) tested caloric compensation and observed mean COMPX of 104% ±107% SD, but no relationship with child weight. Another study administered low-energy (187 kcal) and high-energy (389 kcal) muffin and orange juice preloads, as well as a no-energy preload (water), followed 90 min later by an ad libitum lunch including items such as ham, cheese, carrots, cucumbers, crackers, juice and water, in a sample of 6–9 y olds tested in a laboratory setting and found that younger children showed greater compensation, but compensation ability was unrelated to child weight (Cecil et al., 2005). In a study of 3–6 year olds, intake of a standard lunch containing beef lasagna, cheese, carrot, apple puree and white bread was measured on separate days at the school canteen at lunch time, once 30 min after a chocolate bun preload (137 kcal) and once with no preceding preload, and children compensated 52.5 ± 4.4% SD but compensation was uncorrelated with child BMI z score (Remy, Issanchou, Chabanet, Boggio, & Nicklaus, 2015).

Associations between weight and compensation may depend somewhat on the choice of preloads. This is illustrated by several studies administering varying forms of preload test within the same sample, and matching characteristics such as caloric content, flavor and appearance between preloads (Bellissimo et al., 2008; Brennan et al., 2012). For example, in a study of 9–14 y old boys, although only obese children failed to compensate with whey protein drink preloads, there was no association with weight when glucose preload drinks were used (Bellissimo et al., 2008). In another study, (Wilson 1991) found that preschool children ate 25% more total energy when served chocolate milk with their meals compared to plain milk. Further, in a study of obese and lean adults, while both groups showed hunger and energy reduction at a buffet meal 180 min later following a high protein preload meal, the obese group failed to demonstrate the energy reduction following a matched high fat preload meal that the lean group showed, and relative to the lean group, showed increased energy intake following high fat and high carbohydrate preload meals, but not after high or adequate protein preload meals (Brennan et al., 2012). These mixed findings may partly result from differences in the relative satiating ability of different dietary components (Rolls, 2009; Westerterp-Plantenga, 2003) but also potentially due to differences in palatability (Yeomans, Blundell, & Leshem, 2004) or previously established eating habits.

Certainly, energy intake regulation during free-living eating behavior may be influenced by previously learned expectations of energy delivery (Forde, Almiron-Roig, & Brunstrom, 2015), which are often artificially equated within preload studies using disguised manipulation of energy intake (e.g. Faith et al., 2004; Fricker et al., 1995; Johnson & Birch, 1994; Kral et al., 2012). For example, if we consume a thick milkshake, the perceptual and gustatory experience may consciously or subconsciously activate associations with increased post-ingestive satiety sensations which could lead us to substantially decrease our intake at a subsequent meal, even before macronutrient-dependent post-ingestive satiety effects peak 1–2 h after preload ingestion (Adrian et al., 1985). In contrast, if we consume a calorie-dense version of a beverage that we customarily consume in a less calorie-dense form (as in disguised preload studies), we may consciously or subconsciously underestimate post-ingestive satiety, leading to a failure to compensate (Gibson & Wardle, 2001). Energy intake in an experimental setting could also depend on habits independent of macronutrient-related satiation or learned expectations of satiety. So, for example, habitual consumption of a familiar beverage in close proximity to a meal may lead to inadequate compensation for its caloric load in situations where the caloric load is unusually high.

Although a few studies have examined the effects on compensation of varying preload types, fewer studies have asked the opposite question, i.e. might associations between weight and compensation depend on the composition of the ad libitum meal that is made available? However, one study of young adult men (BMI 21.3 ± 0.5) found that in response to both a low-energy and a high-energy preload of instant soup, subjects ate significantly more, and compensated less, when offered a palatable (pasta with sauce) rather than a bland (plain pasta) lunch (Yeomans, Lee, Gray, & French, 2001), highlighting a potential role for palatability and energy density. As far as we are aware, no studies have addressed the issue of how differing energy preloads affect the composition of the meal that is selected and consumed by participants when they are given access to a multi-item ad libitum meal, and whether this is associated with weight. For example, is the poorer compensation that has been reported in overweight individuals predominantly attributable to hedonic overeating of highly palatable high-calorie foods, or to indiscriminate overeating of all food groups? This is of interest, because if it is the high-energy/junk foods in particular that are being overeaten, then limiting available foods to relatively healthy core food items may improve compensation behavior.

Many of the discrepancies in previous preload studies are likely to relate to methodological variance between experiments (e.g. differences in preloads, length of preload-meal gap, constituents of ad lib meals, age of sample), and some of the negative findings in particular may be the result of extraneous influences affecting the single preload test conducted. In this study we therefore wanted to address two main questions: 1) Is compensation *consistently* impaired in heavier children across *two different types of preload manipulation*– one involving organoleptically indistinguishable preloads varying only in carbohydrate content (low vs. high energy orange, e.g. Faith et al., 2004; Johnson & Birch, 1994) and one involving familiar beverages varying substantially in both macronutrient composition and sensory properties and thereby learned gustatory cues to caloric content (water vs. milkshake, e.g. Bellissimo et al., 2008; Remy et al., 2015)? 2) If compensation is impaired, what are the microstructural characteristics of the impairment, i.e. do heavier children fail to compensate specifically in terms of their intake of obesogenic junk foods, of core foods, or across all food groups? To do this we recruited a sample of 4–5 y