Energy compensation in enterally fed children

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Abstract

Limited exposure to solid food in early childhood may affect the development of appetite regulation. We used formal satiation studies to assess energy compensation in children who have been artificially fed. Subjects were 11 children, median age 4.5 years (range 1–10) who were formerly (n = 4) or currently (n = 5) mainly tube fed or supplement fed (n = 2), with a range of surgical or neurodevelopmental problems. On 2 separate days a high-energy preload (HEP) and low-energy preload (LEP) drink were given followed by a multi-item test lunch. A compensation index (COMPX) score was derived as follows: COMPX (%) = [(Mealhep – Meallep)/(Preloadhep – Preloadlep)] × 100. The median (range) COMPX of the participants was 70% (73% to 178%). The 8 boys tended to compensate more (median 99%) than the 3 girls (median 0%), but there was no clear association of compensation with age. Although a small preliminary study, this suggests that children who have been artificially fed demonstrate energy compensation comparable to that of normally fed children.

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Introduction

Enteral feeding, via gastrostomy or nasogastic tube provides vital nutritional support for neonates and infants with major medical or surgical problems who are unable to meet their dietary requirements through normal oral intake alone. However, when the acute medical issues preventing feeding have resolved, some infants seem unable to make the transition to oral feeding and in extreme circumstances may remain dependent on enteral feeding for years, despite being apparently capable of eating (Mason, Harris, & Blissett, 2005). Children in these circumstances often appear to have no interest in food and may lose weight rapidly when their feeds are reduced (Wright, Smith, & Morrison, 2010).

This leads to the suggestion that such children may have disordered appetite and energy regulation, either as a result of their underlying condition or because of the disruptive effect of long-term tube feeding. All individuals need to be intrinsically capable of regulating their nutrient intake to maintain energy balance. Healthy children have been shown to demonstrate energy self-regulation both in the short term, adjusting energy intake in response to food or drink consumed before a meal (Birch & Deyscher, 1985, 1986; Birch, McPhee, Bryant, & Johnson, 1993; Birch, McPhee, & Sullivan, 1989; Hetherington, Wood, & Lyburn, 2000; Shea, Stein, Basch, Contetto, & Zybert, 1992) and the longer term, over 24 h (Birch, Johnson, Andresen, Peters, & Schulte, 1991).

Satiety is a complex process governed by negative feedback resulting from gastric and duodenal distension, release of peripheral appetite suppressing (anorexigenic) signals, such as leptin, and stimulation of the central suppressive leptin–melanocortin pathway, which communicates with the paraventricular nucleus or “satiety centre” (Druce & Bloom, 2006). Satiety is also dependent upon inhibition of positive feedback from the appetite-stimulating (orexigenic) pathway, including orosensory stimulation (Druce & Bloom, 2006). Meal termination ensues when opposing positive and negative afferent feedback signals are of equal force (Norton, Anderson, & Hetherington, 2006). However, psychological food motivation and environmental stimuli may override physiological regulation of food intake (Bellisle & Dalix, 2001; Blass et al., 2006; De Castro, 1994; Hetherington, Anderson, Norton, & Newson, 2006; Lumeng & Hillman, 2007; Mrdjenovic & Levitsky, 2005; Norton et al., 2006; Shide & Rolls, 1991).

Artificial feeding could affect both physiological appetite regulation and eating behaviour in many ways. Tube-feeding bypasses part of the upper gastrointestinal tract, so that long-term enterally fed children may lack innate somatic satiety cues. The child may also have missed a critical period of associative learning (Birch, 1998; Hetherington, 2002; Rolls, Engell, & Birch, 2000) and have disordered daily eating patterns (Poustit et al., 2006). Other studies have suggested that both the age at which tube feeding started (Mason et al., 2005) and when reduction in feeds began (Wright et al., 2010) may critically affect the ease of transition.
The effectiveness of appetite regulation can be assessed objectively, by measuring short term energy compensation. A preloading experimental model was first used in adults by Booth, Campbell, and Chase (1970), who demonstrated that consuming a glucose “preload” prompted a reduction in energy intake during a subsequent test meal, with the reduction approximately equal to that of the preload energy content. This model has since been developed and used extensively in children (Birch & Deysker, 1985, 1986; Birch et al., 1989). The Birch model compares how children adjust their energy consumption, during two standardized ad libitum test meals, eaten 30 min after a solid or liquid snack (“preload”), which varies only in energy content: high energy in one condition, low in the other. This model has been widely tested in healthy children, particularly in relation to obesity risk (Cecil, Palmer, & Wrieden, 2005; Johnson & Birch, 1994; Johnson & Taylor-Holloway, 2006; Mndjenovic & Levitsky, 2005). On average, after a high energy preload, infants and preschool children reduce their meal intake by between 50% and 100% (Birch & Deysker, 1986; Johnson & Birch, 1994) of the energy content of that preload, but older children compensate much less (Cecil et al., 2005; Johnson & Taylor-Holloway, 2006). Only one previous study has examined energy regulation in a clinical group: this study (Kasese-Hara, Wright, & Drewett, 2002) found that weight-faltering children seemed not to compensate; they ate the same, smaller amount after both high and low energy preload. No studies have yet formally assessed energy regulation in enterally fed children.

The aim of this study was to establish if children who are currently or formerly enterally fed demonstrate energy compensation in laboratory-based satiation studies. We predicted that artificially fed children would demonstrate poor energy compensation, because of limited exposure to solid food in early life.

Methodology

Participants

Children were recruited from the feeding clinic at the Royal Hospital for Sick Children, Glasgow, set up specifically to assist the withdrawal of children from artificial feeding (Wright et al., 2010). The hospital provides tertiary care for the West of Scotland and manages a range of severe medical and surgical conditions. Most of the children referred have survived major neonatal health problems and many remain chronically ill or impaired. Children attending the clinic at the time of the study (June 2006–March 2007) were invited to take part if they were aged between 1 and 10 years, were being or had been enterally fed and were able to take at least some food orally. Ethics approval for this study was granted by Yorkhill Local Research Ethics Committee. Written informed consent was gained from the parents before commencing the first satiation study.

Procedure

The studies were conducted by 2 research students (LK and WF) between July 2006 and March 2007. Parents of eligible children were sent a letter of invitation and an information sheet, followed up by a telephone call. Parents who agreed to take part were given a menu from which they selected a number of foods that their child was likely to eat at the test meals. Each participant then attended two lunchtime sessions roughly one week apart, at the Laboratory for Human Ingestive Behaviour, Glasgow Caledonian University. Parents were asked to fast their children for at least 2 h prior to each study, and researchers assessed compliance by informally asking participants what they had eaten that day.

Before each meal, the participant was presented with a high-energy preload (HEP) drink or low-energy preload (LEP) drink, which they were encouraged to finish. Children who were unable to drink the whole preload and who were tube fed, received the drink via their nasogastric or gastrostomy tube. Participants received the preloads in a random order and the child and family were not told which was which. The preloads of choice were based on a blackcurrant-flavoured soft drink (‘Ribena’) and prepared as follows:

- HEP (200 ml = 506 kJ): 50 ml blackcurrant ‘Ribena’ mixed with 130 ml bottled still water and 20 g of maltodextrin (‘Maxijyl’).
- LEP (200 ml = 1.25 kJ): 50 ml blackcurrant ‘Really Light Ribena’ mixed with 150 ml bottled still water.

Where participants would not take the standard ‘Ribena’ preloads, alternatives were offered (Table 2). Where possible the energy content of the alternative preloads was then matched to that of the standard ‘Ribena’ preloads (506 kJ and 1.25 kJ), so that if necessary the preload volume varied.

Thirty minutes after the children consumed the preload, they were presented with their pre-selected multi-item lunch, served on a tray. Participants ate the meal ad libitum, with normal parental feeding assistance or encouragement (such as spoon feeding, cutting up or handing food, depending on developmental stage) and the meal ended when children demonstrated signs of satiation as determined by the parents, such as stopping eating, refusing to be fed further or saying that they were full. Again this was dependent on developmental stage. Participants were offered the same selection of foods on both occasions.

The preload volume consumed was recorded. Each item was weighed before and after the meal using digital scales (SECA). Energy intake for all items was calculated using energy values supplied by the food manufacturer. Efforts were made to take spillage into account.

Analysis

The primary outcome measure was the compensation index (COMPX) score, derived from the various energy intakes as follows:

$$\text{COMPX} (\%) = \left( \frac{(\text{Meal}_{\text{lep}} - \text{Meal}_{\text{hep}})}{(\text{Preload}_{\text{hep}} - \text{Preload}_{\text{lep}})} \right) \times 100$$

The COMPX (Birch & Deysker, 1985) reflects the precision of energy compensation. 100% represents perfect calorie for calorie compensation.

Because of the small numbers it was often unclear whether the data were normally distributed, so the Mann–Whitney U tests were used to compare participant subgroups. The differences in total meal energy intake within individuals were normally distributed, so a one sample t-test was used for these.

Results

Twenty-four children were eligible and invited to take part in the study. Of these, eight families declined consent and two children (twins) were out of the country. Three families wished to take part, but were unable to complete one or both stages due to illness or other competing commitments. Thus 11 children (3 girls, 8 boys) completed both sessions. All had been enterally fed for between 6 months and 6.6 years because of a range of medical and surgical conditions (see Table 1) but 5 had already stopped, 1–23 months previously.

The individual and median energy intakes are shown in Table 2. Alternative preloads were needed for 4 participants, two of which were of lower volume (80 and 120 mls) in each condition, and two of lower volume (100 and 110 mls) for the LEP only. About half...
the children drank the entire preload volume on both occasions, but all took 80% or more. Energy intake at meals was also extremely variable, but the median energy intake during the meals following the LEP was 412 kJ higher than those following the HEP (Table 2, Fig. 1) and the mean difference (346 kJ) was significantly different from zero (one sample t-test \( p = 0.013 \)). The median (mean) COMPX score of the 11 children was 70% different from zero (one sample t-test \( p = 0.013 \)). The median (mean) COMPX score of the 11 children was 70% different from zero (one sample t-test \( p = 0.013 \)).
Five children showed partial compensation of between 30% and 82%, and another slightly overcompensated (116%), while 2 others showed paradoxical compensation (−73% and −37%) and ate more after the high energy preload. There was a trend for boys to compensate rather more accurately (median 99%) than girls (median 30%; \( P_{\text{Mann–Whitney}} = 0.1 \)) (Fig. 2) but no clear trend to reduce compensation with age or with whether currently tube-fed (Fig. 2). There was also a trend towards worse compensation in those with the longest duration of tube feeding (Spearman’s rho = −0.44, \( p = 0.17 \)) an effect that seemed to be independent of age (Fig. 3).

**Discussion**

This was a small study in a highly heterogeneous sample, but it nonetheless produced results quite similar to those seen in healthy children (Birch & Fisher, 2000; Cecil et al., 2005; Hetherington et al., 2000). Despite the impression that members of this clinical group do not experience hunger and satiation, all but 2 of the children reduced their subsequent meal intake after a high energy preload. The range of responses was wide, but similar wide ranges have been described in healthy children (Johnson, 2000; Johnson & Birch, 1994).

The trend for boys to compensate more accurately than girls has also been described previously (Davy, Van Wallegheen, & Orr, 2007; Johnson & Birch, 1994). In healthy children the precision of energy intake regulation usually declines as age increases (Birch & Deysher, 1986; Cecil et al., 2005; Hetherington et al., 2000; Johnson, 2000; Rolls, Dimeo, & Shide, 1995). This trend was not seen in this small sample, but many of the younger children were the ones who were still tube fed, which may also explain why current tube feeding did not seem to be associated with degree of compensation.

**Practical difficulties**

Recruitment and attendance were extremely difficult in this group due to conflicting medical appointments and illness during the study period. For example, one participant failed to complete the study as he was admitted to intensive care before completing the second feeding session. The children, as a group, tended to be highly selective eaters and the researchers had to modify the standardized menu to accommodate each child’s preference. The neophobic tendencies of the children, combined with their limited repertoire of foods, resulted in a marked between-participant variation between the preload drinks and the foods presented as test meals, but all children received the same meal on both test occasions.

Even when foods the child liked were offered, intake was relatively low, with an average of only 975 kJ taken at the meal after the low energy preload. This is much lower than 1700 kJ per meal on average which participants of this age would be expected to eat at a meal, but some of this difference reflects the fact that they were also, on average, very small children, with lower requirements.

This fussiness also extended to the preloads. For example, one child would not drink anything except his high energy formula milk. Using certain preloads prevented blinding, as the researchers were unable to mask drinks that varied in colour, viscosity, taste and smell. However, blinding was achieved in 8 of the 11 children studied. The lack of preload uniformity also imposed inter-child
volume and energy-density inconsistencies, but these were necessary in order to ensure a consistent energy content. This meant the volume or energy density offered for some children was more than twice that offered to others, but in all but 2 cases, the volume offered on each meal occasion to a given child was the same.

Strengths and limitations

A great strength of this study is that it tests the compensation model in a clinical group, rather than in healthy children. Only one previous study has examined compensation in a clinical group: comparing children with idiopathic weight faltering to healthy community controls. In that study the weight faltering children ate far less than did the controls at both meals and showed no evidence of compensation. The children in our study were selected because of prior illness and tube dependency rather than under eating and the very different result probably reflects their different clinical characteristics.

Although small, this study was conducted as rigorously as possible, but due to the difficulties of working with sick children, numbers were limited and not all aspects of the protocol could be completely observed. Thus these results should be viewed as only preliminary findings. Future work is needed to study a larger group of such children over a longer period, though the logistic difficulties and comparative rarity of this clinical problem will make this a challenging task.

It must be recognised that satiation studies evaluate only short-term energy adjustment, which may not reflect longer-term energy compensation (Birch et al., 1991). For example in our study one child showed little reduction in meal intake after the HEP, but the parents later described him as eating far less throughout the following day. The compensation model captures only 2 meals in a child’s life, and these may not be typical of the child’s normal eating practices. Other studies confirm considerable within-child variation in compensation when studies are repeated (Mitchell, 2009). This group did show highly variable individual responses, as has been shown in healthy children (Johnson, 2000; Johnson and Birch 1994) but this variability may merely reflect the highly variable eating behaviour of all young children (Birch et al., 1991).

Implications for practice

Parents and clinicians often describe enterally fed children as having no sense of hunger or appetite and are reluctant to reduce enteral feedings, assuming that the children will not increase their oral intake to match the amount of feed lost (Wright et al., 2010). These results suggest, however, that the children’s lack of hunger and low intake while on enteral feedings reflects effective compensation, rather than the reverse. These results are also clinically relevant to the use of high-energy supplement drinks, which are commonly used in this sort of clinical group. There has been almost no formal evaluation of high-energy supplements in this age range, but one study found no evidence of long-term efficacy (Poustie et al., 2006). The results of our study, as well as all the prior work in healthy children, would suggest that on average using high-energy supplements in addition to solid food will increase net energy intake only slightly and at the expense of reducing oral intake.

Conclusion

This small study suggests that children who have been enterally fed from an early age may have the same capacity to regulate their energy intake as healthy children.

References


