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The portion size effect and overconsumption – towards downsizing solutions for children and adolescents

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Abstract

Portion sizes of foods offered to consumers have increased at the same time as overweight and obesity levels have risen. It has been suggested that large portions of high energy density (HED) foods increase total energy intake and that this is not compensated for in the short- to medium-term, potentially promoting weight gain. In the laboratory setting, offering large portions of HED foods increases overall energy intake in both children and adults. This phenomenon is known as the portion size effect (PSE), and it is robust, reliable and enduring. The possible impact of the PSE is that large portions served over time may facilitate overeating and could contribute to overweight and obesity. Explanations for the PSE vary from simple heuristics, such as the tendency to clear the plate, to more complex biobehavioural processes, including individual differences in susceptibility to external food cues through eating traits. Consumers may eat in accordance with available consumption norms or eat opportunistically when large portions are made available. An obvious solution to the PSE is to 'downsize' HED meal items and snacks, but whether this strategy is acceptable or feasible is not clear. In adults, the effects of downsizing are mixed and for children and adolescents, as yet unclear. The contention is that for those who are still learning about social norms and appropriate portions, there remains the potential to counter the PSE through downsizing strategies.

Keywords: adolescents, children, energy density, food intake, portion size

Global levels of overweight and obesity among children have increased by more than 50% since 1990 (United Nations Children's Fund 2012). Overweight and obesity can increase the risk of diseases such as type 2 diabetes and hypertension in children (Han *et al.* 2010), and childhood obesity may lead to serious illness in adulthood as well as premature death (Bjorge *et al.* 2008). In 2014, the World Health Organization (WHO) suggested that limiting portion sizes to reduce overall energy intake would therefore also reduce the risk of unhealthy weight gain (WHO 2014). In particular, large portion sizes of beverages, meals and snacks were identified as a potential determinant of overeating. However, before the proposal that large portions are implicated in both overeating *and* obesity is accepted, there are at least four forms of evidence needed to support this. The first is that there are associations between large portions and increased bodyweight at the population level; secondly, that providing large portions at a meal prompts

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overconsumption at the individual level; thirdly, that in the longer term, no adjustment for large portions takes place, producing a net energy surfeit; and finally, that systematic exposure to large portions over time promotes weight gain. Given that energy balance is a dynamic process and that excess adiposity is achieved over time, it is important to consider each part of the portion size effect (PSE) from large-scale epidemiological studies to small-scale laboratory experiments. Each form of evidence will be considered in turn.

Associations between portion sizes and bodyweight

In parallel with rising levels of overweight and obesity, portion sizes of foods served inside and outside the home have increased (Piernas & Popkin 2011). There have been numerous large-scale epidemiological studies demonstrating that portions served to children have increased over time. For example, in a time-series analysis of portion sizes consumed by Australian children aged 2-16 years, recorded between 2007 and 2012, it was found that portions of some high energy density (HED) foods had increased but those of fruit and vegetables decreased over time and were below recommendations (Van der Bend *et al.* 2017). In tandem, levels of childhood overweight and obesity in Australia increased from 10% in 1985 to 26% in 2012. The obvious conclusion from this study is that consuming large portions of HED foods and small portions of low energy density, nutrient-rich foods are linked to overweight and obesity. A cross-sectional study of UK adolescents (n = 636, aged 11–18 years), using data from the nationally representative *National Diet and Nutrition Survey* (*NDNS*), found that large portion sizes of some HED foods (cereals, cream and high energy soft drinks) predicted higher body mass index (Albar *et al.* 2014).

Although it appears parsimonious to link the two, evidence fails to demonstrate a direct causal relationship between portion size and obesity. To infer causality, it must be demonstrated that large portions lead to overconsumption, that this overconsumption is maintained without compensation elsewhere in the diet and that over time large portions promote weight gain.

Short-term laboratory-based studies of the portion size effect

Experiments conducted under laboratory conditions consistently demonstrate that offering large portion sizes of food to children promotes overconsumption. The PSE is the term applied to the observation that more is eaten when large portions are offered compared to small portions (see Fig. 1 for a schematic representation of the phenomenon). The PSE is found in adults and children, and across a number of different meal and snack types. A series of studies have confirmed that the PSE is robust and reliable in young children (see Birch *et al.* 2015 for a review) and in adults (Rolls 2003). In these studies, a main meal or snack is offered in varying amounts, which participants then eat *ad libitum*. Amount consumed is the primary dependent variable and typically large sizes promote large intakes. Although, in one of the earliest studies of the PSE, Rolls *et al.* (2000) gave young (aged 3–4 years) and older children (aged 4–6 years) small, medium and large portions of macaroni and cheese. Only the older children showed the PSE and younger children ate the same amount of energy in each condition. At first, it was assumed that very young children are guided more by internal than external cues to eat, such as hunger more than portion size. However, to date, this study has not been replicated, and most studies have consistently shown that even very young children respond to large portions by eating more (see Kral & Hetherington 2015 for more detail).

Applying meta-analysis to a range of studies examining the PSE in both adults and children indicated that, on average, when portion sizes are doubled, consumption increases by 35% (Zlatevska *et al.* 2014). If young children are exposed to large portions consistently, then this may drive excess energy intakes and, in turn, might result in overweight or obesity. However, as these studies have been conducted within one meal or snack, the question is whether this effect endures beyond the single eating occasion and whether this influences weight gain.

Long-term impact of large portions on energy intake

If consumers overeat in the short-term, when large portions are presented in the laboratory, but then adjust for this elsewhere in the diet, then energy balance is expected to be achieved and weight to be maintained over time. Studies have been conducted over many days to examine the impact of large portions on energy intake and over many months to determine the longer term effects on energy balance. In studies where portions have been manipulated from meal to meal, no adjustment in total energy

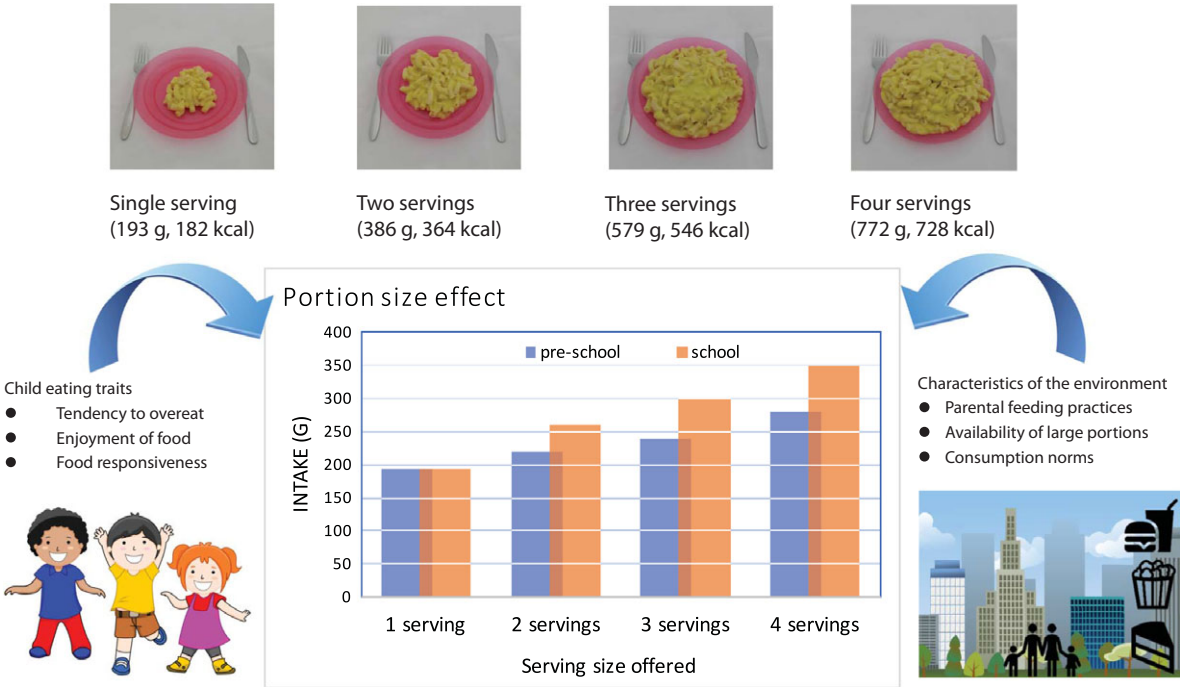

Figure 1 An illustration of the portion size effect (PSE) in children. Upper panel: increasing serving sizes of macaroni and cheese; middle panel: a schematic representing *ad libitum* intake across the serving sizes comparing pre-school and school-age children; side panels: factors known to influence the PSE in children (eating traits, environment). [Colour figure can be viewed at wileyonlinelibrary.com]

intake has been observed. For example, Rolls *et al.* (2006) examined the PSE over two days, for three consecutive weeks. Adult participants were provided with breakfast, lunch, dinner and two snacks in the laboratory, on two consecutive days. The portion size given in each week was either a standard size (100%), 150% or 200% of this amount. With an increase of 50% in portion size, intake was increased by 16%, and with an increase of 100% in portion size, intake was increased by 26%. Therefore, the PSE was sustained over two days with no adjustment made on the second day for large portions offered on the first day. In a subsequent study extended over 11 days, all foods and beverages were provided in a laboratory setting in standard or large (150%) portions (Rolls *et al.* 2007a,b). Overall, no adjustment to total energy intake for the larger portion size was made and so a 50% increase in portion size resulted in an additional energy intake of 423 kcal per day and a cumulative additional energy intake of 4636 kcal over 11 days. For women, the increase in intake was around 25% and for men was 14% of total energy intake. The magnitude of this effect was comparable to that found in the earlier two-day study. Therefore, given that large portions encourage overconsumption over time, then the proposal that large portions might contribute to overweight and obesity is plausible.

Long-term impact of large portions on weight gain

To examine the impact of large portions on energy balance and specifically changes in bodyweight, studies must be conducted over many months rather than days. In a workplace study in which participants were given small or large lunches over a period of 2 months, Jeffery *et al.* (2007) found a modest increase in bodyweight in the large lunch condition. In a larger workplace study over a 6-month period, adults were assigned to a small (400 kcal), medium (800 kcal) or large (1600 kcal) lunch group (French *et al.* 2014). Total energy intake was significantly higher in the large lunch condition compared to the other conditions. Within the large lunch condition, participants gained about 1 kg of bodyweight, which was significantly different from baseline but not significantly different from the other groups. Indeed, the control group also gained about 1 kg of bodyweight over the period of the study, but participants in the small and medium lunch conditions maintained energy balance. It is hard to interpret these findings except to

suggest that smaller lunches given over the 6-month period helped participants to remain weight stable.

Pre-portioned foods have been used to assist in weight loss (Wing & Jeffery 2001). The success of this strategy may be due, in part, to encouraging consumers to eat fixed amounts of appropriate sized portions rather than eating *ad libitum*, self-served amounts. Also, it relieves the consumer from having to work out amounts to prepare and serve. In two recent weight loss studies, portion control strategies (including provision of pre-portioned meals) as part of a 12-week (Rock *et al.* 2016) or a 12-month (Rolls *et al.* 2017) weight loss trial facilitated early weight loss. However, in the 12-month trial, portion control strategies did not lead to a greater weight loss than standard advice. Using pre-portioned foods as part of a portion control strategy may be successful during the initial period of weight loss and during the period of food provision (Wing & Jeffery 2001), but portion control did not result in good adherence nor long-term sustained weight loss (Rolls *et al.* 2017).

Explanations for the portion size effect

A variety of explanations have been put forward to account for the PSE. Consumers may make a perceptual error when offered large portions and not realise they have overeaten. This is supported by evidence that the energy content of large portions tends to be underestimated, especially for HED foods (Almiron-Roig *et al.* 2013). However, adult participants in PSE studies will often correctly identify that portion size has been manipulated (so they are aware of the differing sizes offered) and under some circumstances recognise that portion size was a factor in determining intake. For example, Vartanian *et al.* (2017) discovered that when participants said that they had consumed more than their typical amount, they then identified portion size as an influencing factor. Vartanian and his colleagues have coined the phrase 'motivated denial' to capture the idea that individuals consider the large amount served justification for overindulgence.

For children, at least, a more simple, heuristic explanation for the PSE is the tendency to 'clean the plate' as a result of parental influence (Birch *et al.* 1987). Children might view external cues, such as food served on a plate, as a prime to eat and the amount served as a prompt for how much to eat. Also, the size of the dishware used might set the intake norm. DiSantis *et al.* (2013) investigated the effect of plate size in first-grade schoolchildren. They were given adult or child-size plates and asked to serve themselves lunch (pasta on one day and chicken nuggets on another day). Children served themselves 90 kcal more when using the adult compared to the child-size plate, across both foods (DiSantis *et al.* 2013).

There is strong evidence to show that children eat most of what is served to them by parents (Johnson *et al.* 2014). In this study, researchers measured amounts offered and consumed at a meal by children and parents during three home visits. The amounts served to children explained 73% of the variance in children's intake and large portions resulted in large intakes. Additionally, the amounts parents served themselves strongly correlated with the amounts served to their child (Johnson *et al.* 2014). Therefore, parents are guiding their children's intake of food by establishing portion norms and imparting an expectation that the amount served should be eaten. In low-income households, children may be expected to 'clean the plate' to avoid waste, but this strategy shifts reliance away from internal cues of hunger and fullness to external cues of portion size. If the amount served on the plate signals the amount to be eaten, then children may be expected to eat more than they need (or want).

However, if this simple heuristic to clean the plate was the main explanation of the PSE, then there would be a clear dose–response function between portion size and energy intake. But investigations of the PSE combining multiple studies ($n = 65$) across adults and children reveal that there is a curvilinear function between portion size and intake (Zlatevska *et al.* 2014). This suggests that rather than a simple plate clearing strategy, consumers will eat a certain amount of what is offered but that how much they eat will be determined, in part, by internal cues of satiation (not merely the external cue of amount served), social norms or unit bias, and individual differences. Results presented from studies of the PSE provide average intakes and mean increases in energy intake, which masks individual differences in the extent to which consumers are influenced by the presentation of large portions.

Who is most susceptible to the PSE?

Individual characteristics predict dietary intakes and may be important in determining who is most likely to overconsume when large portions are available. As a general rule, the tendency to eat according to external cues, such as when food is available, predicts

overeating, whereas the tendency to eat according to internal cues of hunger and satiety limits food intake. Food approach traits, such as external responsiveness, should predict a greater magnitude of the PSE than food avoidance traits, such as food fussiness or satiety responsiveness. These traits in children are generally measured using parental reports, such as the Child Eating Behaviour Questionnaire (CEBQ; Wardle *et al.* 2001). For instance, children reported to be highly food responsive are more likely to be influenced by portion size than those with high satiety responsiveness, who depend more on internal cues to determine food intake. In their study of portion size and energy density, Kling *et al.* (2016) found that children with a high score on the CEBQ for food responsiveness showed a much stronger PSE than those with a low score. Similarly, they found that parents who tended to monitor their child's food intake due to concerns about overeating also showed a stronger PSE than children whose parents tended not to monitor food intake. Therefore, individual differences in susceptibility to the PSE are worth exploring in more detail, as it could be that portion control strategies either for promoting healthy eating in children or helping adults in weight management may need to be tailored to the individual. Whilst eating traits are highly heritable and can be difficult to modify (Llewellyn *et al.* 2010), learning about appropriate portion sizes for particular foods (such as those high in fat, sugars and salt) especially in children might mitigate against the tendency to overconsume.

Downsizing strategies

So far the evidence suggests that offering large portions of food promotes an increase in energy intake with a potential link to both overeating and weight gain. One possible solution to the PSE is to 'downsize' portions, particularly for HED foods and beverages. This can be achieved in a number of ways. The most obvious is to provide smaller size meal items, snacks and drinks, assuming that consumers will not adjust for this. This assumption has been supported by a study conducted by Lewis *et al.* (2015). They presented adults with a standard breakfast, a 20% smaller breakfast and a 40% smaller breakfast on three separate days. They measured ratings of appetite, gut hormone secretion and subsequent energy intake for the remainder of the day (test meal at lunch, *ad libitum* snack intake, food diary for evening intake). They found that energy intake at lunch and for the rest of the day did not differ by breakfast condition, but at least one of the biomarkers of appetite and the subjective ratings of appetite were sensitive to the reduction in portion size. The 40% smaller breakfast produced a net reduction in daily energy intake. However, the authors of the study question the sustainability of consuming this size breakfast since appetite, incretin hormone release and perceived meal size ratings were responsive to the reduction.

Another downsizing strategy might relate to the way food and beverages are presented through packaging and dishware. Mantzari *et al.* (2018) have investigated the feasibility of swapping large volume bottles of sugars-sweetened beverages for smaller size bottles. In this study, 16 households received the usual amount of cola they would consume over a week presented in the form of small (250 ml), medium (500 ml), large (1000 ml) or extra large (1500 ml) sizes, each week for 4 weeks. Overall, the families reported that the small bottles increased drinking occasions citing greater convenience and portability among reasons for greater perceived consumption. Therefore, downsizing in this study failed to produce the desired impact.

Robinson and Matheson (2015) have proposed using small size dishes for meals and tall, thin, low volume glasses for beverages. However, for adults, a small dish size prompted more trips to a buffet bar to obtain more self-served food items (Rolls *et al.* 2007a, b); therefore, dishware size alone may not be sufficient to encourage portion control. In two experiments where dishware was designed with in-built portion indicators, it was found that this visual aid reduced the amount of self-served food at a meal in US university students (Hughes *et al.* 2017). By encouraging small portions, the small plates reduced overall energy intake; however, the participants also served smaller portions of vegetables than is recommended. Clearly, this is not ideal as most young people fail to eat enough vegetables. Therefore, experiments which downsize HED snacks and meal items are needed to investigate whether children tolerate smaller portions and whether there are unintended consequences of downsizing, such as compensation elsewhere in the diet.

Downsizing for children, adolescents and families

Given the mixed success of downsizing strategies with adults, the next step is to test whether children and adolescents will accept smaller portions of HED foods. It is not clear whether downsizing will work in these age groups. However, there is sufficient evidence to

suggest that learning, nudging or packaging could be used to inform studies to suit the age and stage of the child. Therefore, a series of studies have been devised to investigate this. One study, a randomised control trial, has been designed to test the feasibility and acceptability of reducing snack portions using either a reduction (by 50%) or replacement strategy in which HED snacks were swapped for fruit, vegetables and a breadstick, cracker or rice cake (registered trial, ClinicalTrials.gov NCT03339986).

It will be interesting to discover whether these strategies are acceptable. In previous research, parents struggled with quantifying appropriate portions for children and adjusting portions was considered effortful and inconvenient (Curtis *et al.* 2017). Evidence from a qualitative study by Blake *et al.* (2015) of 60 low-income families found that portion size control strategies used by parents included using small containers and measuring cups to subdivide large portions and purchasing small pre-packaged snacks. Parents need support in determining appropriate portions especially when purchasing large, family size packages of HED snacks, which offer better per unit value but where it is hard to judge appropriate portions for children. Food manufacturers might consider offering snacks in smaller, child-size portions or providing scoops and other aids for portion control. However, whether these will be effective is not yet known.

In another trial, energy-dense meal items will be the primary target of downsizing as these typically contribute most to total energy intake (Kling *et al.* 2016). In particular, it is not known whether children might compensate for a smaller meal item by eating more of a low energy density side dish (Cecil *et al.* 2017). This is relevant to the goal to increase intake of nutrient-rich foods, such as fruit and vegetables, whilst reducing intake of energy-dense, nutrient poor foods. However, simply providing large portions of fruit and vegetables in competition with highly liked meal items may not produce the desired effect on overall intake (Kral *et al.* 2010).

For adolescents, a social media framed nudging study has been designed to evaluate this method as a way to model appropriate portion size snacks for this age group (Sharps *et al.* in preparation). In previous health interventions, platforms such as Facebook (Pedersen & Kurz 2016) have been used both to recruit young people and to engage in health-oriented interventions. A systematic review of social media interventions found that improvements in some aspect of health behaviour were found in most studies, but the effect size was small (Maher *et al.* 2014). Therefore, while social media provides an individually relevant means to reach young people, changing behaviour around diet, including portion size control, might be challenging.

Another promising area to explore involves packaging, as the unit bias concept predicts that single item packs provide a portion size guide in much the same way as amount served by parents or investigators in PSE studies. In this area of research, packaging solutions will be investigated to assist parents in serving appropriately sized portions of food to their children (see https://youtu.be/-_D3cjVCTbg). It is not clear where packaging or provision of single units of food can promote lower intakes of HED foods. Indeed, Kerameas *et al.* (2015) found that participants ate less when offered the same amount of a snack food served in multiple units than as a single unit (individually wrapped). Simply dividing up and packaging a HED food in smaller units can help consumers limit intake, compared to a single, larger unit. However, as was observed by Mantzari *et al.* (2018), smaller unit size can also drive intake in the long-term through increased appeal and ease of access.

Conclusions

The PSE, in which more food is consumed when more is offered, is a robust and reliable phenomenon in laboratory settings. The evidence is clear that if large portions are offered over many days, intake will be increased. However, the evidence is less convincing that this necessarily leads to weight gain. What is apparent is that sustained intake of large portions of high energy-dense, nutrient poor foods is contrary to healthy eating advice, including that from WHO (WHO 2014). Some consumers are more susceptible to the PSE than others and this seems to be related to sensitivity to external cues, such as the availability of highly palatable, energy-dense foods (Fig. 1). Therefore, downsizing strategies may need to be tailored to fit the age, stage and characteristics of the consumer. To date, efforts to provide small portions of foods or beverages to reduce intake have produced mixed results in adults. This may be due to awareness of smaller than usual portions, and so consumers feel hungry or that they have missed out on their typical amount. It could be that small size packaging is attractive, portable and convenient but might inadvertently increase consumption. However, in children, there is the opportunity to shape expectations about appropriate portions—namely 'me-size' amounts (*e.g.* UK government *Change4Life* campaign http://change4lifewales.org.uk/families/mesize/?lang=en). In addition,

for adolescents, who are also establishing dietary habits and food choices, there is the chance to intervene to encourage downsized portions. It is imperative to investigate the impact of downsizing and to provide an evidence base for parents to adjust children's portions of meal items and snacks to suit their needs and appropriate to their size.

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