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Lead Article

Portion-size reduction: A review of evidence supporting current strategies, challenges, and opportunities

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ABSTRACT

While there is considerable evidence for the portion-size effect and its potential impact on health, much of this has not been successfully applied to help consumers to reduce portion sizes. The objective of this review is to provide an update on the strength of evidence supporting strategies with potential to reduce portion sizes across individuals and eating contexts. Three levels of action are considered: food-level strategies (targeting commercial snack and meal portion sizes, packaging, food labels, tableware, and food sensory properties), individual-level strategies (targeting eating rate and bite size, portion norms, plate cleaning tendencies and cognitive processes), and population approaches (targeting the physical, social and economic environment, and health policy). Food and individual-level strategies are associated with small to moderate effects, however in isolation, none seem to have sufficient impact on food intake to reverse the portion-size effect and its consequences. Wider changes to the portion size environment will be necessary to support individual and food-level strategies leading to portion control.

Keywords:

downsizing, portion size effect, obesity, eating context, eating behaviour

INTRODUCTION

There is now convincing evidence that exposure to large portions of high energy-dense foods results in increased energy intakes, a phenomenon known as the *portion-size effect*¹⁻³, and observed across a variety of food types, environmental conditions, and study populations⁴. Because portion sizes have increased in recent years⁵⁻⁷, this phenomenon requires individuals to invoke personal coping strategies to avoid overconsumption⁸. Evidence for a potential association between increased portion sizes and obesity comes mostly from laboratory and field studies linking the consumption of large portion sizes with increased energy intakes across a variety of food types, age groups, and body weights^{2,4,9}. In addition, a small number of studies indicate that serving smaller portions may help to reduce daily energy intakes¹⁰⁻¹³, however the longer-term effects of reducing portions are less clear¹⁴. While more observational studies are needed¹⁵, if reduced intakes can be sustained, then portion-reduction strategies might confer benefits at the population level³. Currently, little is known about how to support people to eat smaller portions, beyond education or the use of food labels, which have demonstrated limited success^{16,17}.

The mechanism(s) underlying the portion-size effect remains unresolved. However, several processes have been proposed^{1,4,9,18}. Factors that may contribute include ways in which the portion is served or presented (e.g., meal and snack portion size and packaging cues, unit number and size, presence of segmentation cues, size of tableware, calibration marks on packaging or tableware); ways in which the portion is eaten (e.g., plate cleaning tendencies, bite size/eating rate, attention while eating), ways in which portion sizes are perceived (e.g., 'appropriateness' or portion size norms, familiarity, expectation, awareness and estimation biases), and other factors that interact to influence such perceptions (e.g., palatability and energy density). In addition, external factors such as value for money and packaging information can also affect decisions about how much is purchased, self-served, and consumed.^{3,9,18} Overall, consumers may rely on the amounts served or contained in a package

as a simple heuristic to determine intake, balanced with consumption norms, taste, expectations and/or prior experience¹⁹.

Recent robust meta-analyses have shown that manipulations to portion size can have a strong impact on eating behavior^{2,3,20}. However, much of this information has not been successfully translated to help consumers to reduce self-selected portion sizes at the population level²¹. Educational public health campaigns and observational studies suggest that portion sizes are still large, especially for high energy density foods and caloric drinks^{6,15,22}. It has been suggested that without modifying the environment in which consumers make portion size decisions, on their own, educational initiatives are likely to have limited efficacy²¹. Another reason for the lack of progress may be that interventions that target weight loss or weight maintenance have tended to focus on successful body weight changes resulting from complex dietary, cognitive, physical activity, and/or pharmacological/medical manipulations, without specifically targeting portion size. This has also led to a general lack of understanding around the effects of reducing portion sizes on consumer perceptions and acceptance, meal satisfaction, satiety, and energy compensation, especially over long periods.

While some portion-size interventions have shown promise, it remains unclear which type of intervention will work best, for whom, and in what contexts^{18,21,23}. Based on the latest evidence, Vermeer et al. (2014)²⁴ recommended more research on strategies for communication and marketing related to portion size, environmental portion size interventions, educational interventions to deal with a 'super-sized' food environment, increased regulation around portion size labelling, and the use of nudging to stimulate healthier portion selections. These recommendations have been echoed by others and actions ranging from doing nothing to eliminating choice have been proposed^{25,26}.

Despite these efforts, practical and evidence-based population-wide guidelines around healthy portion control are still lacking. This review provides an update on current evidence supporting recommended strategies to reduce portion size across individuals and eating contexts. Initially, food-level strategies are considered, followed by individual level and then population-wide approaches, including an assessment of their potential impact and challenges ahead.

METHODS

A narrative review was conducted to provide an overview of the key literature in this area, with additional searches to supplement authors' knowledge. Given the broad scope of this field, the decision was taken not to systematically identify and evaluate all associated literature.

Data searching process

First, meta-analyses (MA) and systematic reviews (SR) exploring the “portion-size effect”, “portion size reduction” and “portion control strategies” were searched via PubMed plus the Cochrane Library. Initial searches were supplemented by an internal database of publications (years 1989-2018). Relevant MA and SR were selected based on title and abstract, or from the full text when information in the abstract and title was unclear. Secondly, to capture recent developments, individual studies covering the same topics were identified from PubMed and the internal database and were selected if not included in any of the previous narrative reviews, SR or MA. Searches were complemented with cross-referencing from the identified publications supplemented by the authors' specialist knowledge of the literature. For all searches the following inclusion and exclusion criteria were applied: INCLUDED: English language, humans, portion control strategies based on food, individual or population-level approaches; MA covering related outcome measures (e.g. on tableware size) when the set of studies examined differed; individual studies related to individual characteristics which may be modulated to control portion size (even if the focus was not on portion size). EXCLUDED: MA quantifying effect size of strategies of different

categories altogether (i.e. not specifying effect size for each individual strategy); editorial/opinion piece. Confirmatory searches were performed using “portion size reduction”, “portion size control” and “portion size labelling” as keywords in the Cochrane Library and PubMed databases during March-Sep 2018. A later meta-analysis²⁷ and two systematic reviews^{28,29}, plus one cross-sectional study³⁰ were added during the revision period.

Data extraction process

Data were extracted by two investigators (EAR and MAV) and disagreements discussed and agreed with a third author from the author team. Extracted data for both reviews and individual studies included strategy level (food, individual or population), timeline, type of evidence, mediators, outcome measure, effect size, plus, for reviews and MA only, overall quality. For MA, when numerical data were not reported or were presented in a different metric to SMD or Cohen’s d, the authors were contacted for information.

The following operational terms were used: *Timeline* of studies: defined as acute (1 day), short term (1 week), medium term (2-3 weeks) and long-term (4+ weeks). *Type of evidence*: based on the American Dietetic Association Evidence Library criteria³¹: **A**= RCT, cluster randomised trial or randomised crossover trial; **B**= prospective or retrospective cohort study; **C**= non-R controlled trial, non-randomised crossover trial; case-control, time series, diagnostic, validity or reliability study; **D**= non-controlled trial, case study, case series, cross-sectional, trend, before-after or other descriptive study; **M**= meta-analysis or systematic review; **R**, narrative review. *Mediators*: variable reported as mediating the effect on the outcome measure. For instance large portion size was identified as a mediator of increased energy intakes. *Outcome measures*: any measure related to the *portion-size effect* and including actual, intended or perceived intake as main outcome measures, in terms of both energy and amount consumed and selected. Secondary outcomes were weight loss, impulsivity, portion size perceptions or estimations, meal satisfaction, enjoyment, subjective appetite, eating behaviour, cognitive (e.g. memory), metabolic and anthropometric outcome measures. *Effect size*: standardised mean differences (SMD) or Cohen’s d. This metric

reflects how much more is consumed from a larger portion size offering than, for example, a smaller or “control” portion size. A positive value for Cohen’s *d* reflects the expected portion-size effect, with a larger mean difference reflecting a larger effect². Magnitude of the effect size was based on Cohen’s *d* criteria³²: $d \leq 0.2$ small; $d = 0.5$ medium; $d \geq 0.8$ large.

Quality evaluation of the studies/reviews

Overall quality for the evidence from MA, SR and narrative reviews was judged based on the summary assessments of quality of the evidence that were reported in each review, including GRADE³³, AHA³⁴ and US Preventive Services Task Force³⁵ evidence quality scores when available. These represent standardised, systematic approaches to assess quality or certainty of the evidence for an effect derived from a group of studies. The heterogeneity index (I^2) is also reported when available as a measure of inconsistency of effect estimates within these reviews (low $I^2=25\%$, medium $I^2=50\%$, high $I^2=75\%$)³⁶. For individual studies, the study evidence level³¹ is reported as general guidance while more detailed limitations are discussed in the text.

After applying the selection criteria a total of 72 publications were included. For one meta-analysis²⁷ effect sizes could not be included in the figures due to different metrics and being unable to contact the authors. The results have been summarised in **Table 1** (all papers)^{2, 3, 12–14, 18, 23–25, 27,37–39, 40–49, 50–59, 60–69, 70–79, 80–87, 88–94, 95}, **Table 2** (meta-analyses results)^{2,3,27,40,52,60,73,78} and **Supplementary Tables S1-S3** (study details).

OVERVIEW OF STRATEGIES TO REDUCE PORTION SIZE

Food level strategies

Food-level strategies for the reduction of portion size include: reduced portion sizes of restaurant and manufactured meals and snacks; reduced pack and container size; packaging with portion size (calibration) markings³; portion size information on food packaging^{17,96}; and modified serving and eating utensils^{3,40,41}. In addition, emerging research in sensory science

and related disciplines suggest that palatability and meal satisfaction might also play an important role in portion control^{42,97} (see Tables 1, 2 and supplementary **Table S1**).

Reduced meal/snack size offerings

Multiple sources of evidence suggest that providing smaller meals may be an effective way to reduce energy intakes^{2,3,8,98,99}. A recent systematic review³ suggests that if sustained reductions to large portions could be achieved across the whole diet then this could reduce average daily energy consumed by up to 16% in UK adults (equivalent to 279 kcals per day) and by up to 29% in US adults (527 kcals per day). Given that portion control is particularly challenging, especially when dieting¹⁸, environmental cues that promote the self-selection of smaller portions should be given serious consideration. For instance, it may be helpful to reduce the size of offerings in restaurants and to provide commercially available portion-controlled meals^{10,11,14} and snacks^{100,25}. However, the positive benefits may be short-lived¹⁴. While consumers may be willing to select reduced portion sizes when offered alongside regular counterparts^{23,101,102}, sustained consumer acceptance of smaller portions is required¹⁰³. This is particularly relevant for palatable foods, such as snacks and drinks consumed in social settings, as other factors such as perceived status¹⁰⁴, context of eating (where and with whom)¹⁰⁵, palatability¹⁰⁶, and expected satiation¹⁰⁷ may override otherwise good-intentioned health-oriented decisions. Importantly, from a health perspective, smaller offerings should not be financially penalized even if consumers expect a quantity discount as this may induce over-consumption¹⁰⁸. However, this is rarely if ever the case – consumers are often expected to pay the same price for a smaller portion, and when price is reduced, this is rarely proportionate to the reduction in size¹⁰⁹.

In response, it has been suggested that smaller portion sizes should be the default rather than an option in restaurants and work canteens (a form of dietary nudging)^{24,25,110}. However, when reduced portion sizes are offered, they need to be perceived as having sufficient energy content¹² and satiation power^{12,46} to satisfy individual requirements. In addition, price

may need to be considered as a mediator of some people's preferences for larger package and portion size²⁶ (the effects of linear vs non-linear price are expanded in a later section).

The feasibility of producing and selling reduced portions requires careful consideration¹⁰³. Reducing unit price poses a significant risk to revenue that is unlikely to be matched by a reduction in ingredient costs. In terms of cost savings, changes to the cost of goods sold (COGS) *per unit* are often negligible and, in some cases, moving to a smaller portion may create new ingredient, distribution, and operational complexities that actually increase costs. Therefore, savings made to COGS are unlikely to be sufficient to drive a profitable price-point when moving to a smaller portion. In restaurants, lowering the price point may increase the perceived value of a reduced-portion menu item, but may also harm revenue and reduce consumer enjoyment of the meal. Relying on consumers to adopt a 'less is more' mindset also poses a risk to repeat business and profitability, and would require the adoption of a sector-wide portion-control strategy¹¹¹. Although both chefs and restaurant owners have expressed concerns about how large portions influence intake, they are likely to regard individual dietary decisions as primarily the responsibility of their customers^{112,113}.

In summary, reduced-size meal and snack offerings in food outlets and supermarkets offer potential as an environmental modification to induce healthier portion-size selections. However, more research is needed to understand the impact of these interventions in different types of foods, settings, and individuals. In addition, the feasibility and consumer acceptance of a market-wide reduction in portion sizes, and the appropriate cost model that sustains both industry profitability and financial value for the consumer, merits further scrutiny.

Package and container size

It is now well accepted that packaging and container format have a strong impact on what people regard as an appropriate amount to eat and then eventually consume, irrespective of

actual volume and energy content^{38,114,115}. A recent systematic review concluded that reducing pack size alongside meal portion size and tableware size could lead to significant reductions in intake, in both adults and children³. However, the efficacy of this approach is predicated on the long-term acceptance of smaller portions. As shown in a later randomized controlled trial, sustained effects of portion-size control strategies remain difficult to achieve¹⁴. While pre-packaged meals may aid greater weight loss over the first 3 months compared with portion-control training or standard advice, afterwards, participants randomized to this intervention also showed more rapid weight regain. One possibility is that participants felt 'deprived' while consuming these meals, leading them to select relatively larger meals after the intervention had terminated.

Unit size and unit number may also influence intake⁴⁵. Studies show that number of packs in multipacks increases the likelihood of consumption^{115,116}. A proposed theory is that compared to multipacks, a single large pack increases the period of deliberation, before the pack is opened¹¹⁶. These effects also seem to depend on individual dietary traits – while the unit size of a multi-pack may not affect total consumption in normal-weight individuals¹¹⁵, it may in people with overweight¹¹⁷. Alternatively, smaller packs may offer an opportunity to take a pause from eating, which may promote a memory for the number of packs consumed¹¹⁷. The pack-size effect may also be moderated by appetite, dietary restraint, gender, and a range of other individual differences^{38,39,45,75,100,118,119}.

Dramatically reducing volume though may be counterproductive, because a lower threshold seems to exist for the portion-size effect. In other words, a marked reduction in portion sizes may actually increase consumption⁴⁶, possibly because very small packs/containers encourage lapses in self-control^{116,120}. In a recent qualitative study⁴⁶ 16 British households were given bottles of 1500, 1000, 500 and 250 ml of sugary soft drinks to consume *ad libitum*. Consistent with the above hypothesis, families reported consuming a greater number

of the smallest bottles and attributed this to their convenience, easier stockpiling, and a difficulty in keeping track of how many had been consumed.

The problem with packaging is likely to stem from visual biases that are inherent (i.e., hardwired) in humans. Perceived size follows an inelastic power function of actual size (i.e., with a power exponent smaller than 1)⁴⁴. In other words, perceived size grows more slowly than actual size¹²¹. Accordingly, as portions increase, their size is increasingly underestimated. In fact, people notice product downsizing much more easily than product supersizing. This is because estimating supersizing is an extrapolation from the reference size whereas downsizing is an interpolation between the reference size and zero¹²². Some evidence indicates that better size-estimation is found when individuals experience an emotional conflict towards hedonic food (for a comprehensive review see⁴⁴). In addition, perceptual distortion also affects the impact of package size on portion selection. These 'dimensionality biases' are particularly likely when packaging size changes in more than one dimension⁴⁴. For example, people find it more difficult to estimate portion size when packaging changes in multiple dimensions (i.e., height, width, and length) than when it changes only in height. The underlying reason is that people find it more difficult to integrate changes along three dimensions at once. Rather than multiplying percentage changes in height, width, and length, people often add these dimension when estimating changes in volume¹²³. Leveraging this effect, downsized packaging may be less likely to be noticed by a consumer when several dimensions are reduced rather than just one¹²⁴. In this regard, one such specific change, *elongation* (when the base of the package decreases while the height increases), has proved particularly successful. In a study using candles and soaps¹²³, a 24% reduction in one dimension (height) was perceived as a 20% reduction, while the same reduction was perceived as only a 2% reduction when elongation (increasing the height while reducing the base) was applied.

Overall, the impact of packaging on portion-size estimation is strong and, in part, is influenced by perceptual biases that are inherent in human visual processing. Nevertheless, reductions in

size that extend beyond the limits of these biases are unlikely to be effective, because they will be readily detected by consumers. To achieve a greater immediate reduction in energy intake reformulation may also be necessary and, in combination, this approach is more likely to yield successful outcomes because covert manipulations to energy density are less likely to be recognised than overt changes to the physical dimensions of products.

Portion size information on food labels and packaging

Similar to energy and nutrient labelling approaches¹²⁵, portion-size information on food packaging (such as providing standardised information on portion sizes) has been proposed as a way to help consumers to select appropriate portion sizes. A recent systematic review of 36 studies²⁸ concluded that nutrition and health information presented on food labels has varying impacts on portion sizes consumed, in part due to inconsistent reporting standards. The effects of labelled serving size information in particular and for non-discretionary foods also remains unclear⁴⁷, with the majority of studies being conducted in controlled conditions and very few in other contexts (e.g., the home, restaurants, and on the go).

'Standardised portion sizing' refers to an attempt to establish reasonable single servings of foods and, in particular, those eaten frequently and that are known to increase the risk of chronic disease. For example, for snack foods and desserts, the standard portion might reflect the maximum recommended discretionary calories for the average adult trying to maintain weight (e.g., 300 calories, according to USDA guidelines)^{26,126}. However, implementing this guidance is non-trivial⁵¹. First, portion-size information is currently presented in a wide range of formats, including numerical - as part of the nutrition information back panel or the front of pack label (FOP)¹²⁷, or as a suggested serving size (typically a food image on the front of the pack). Second, consumers find numerical information to be unclear, inconsistent, and difficult to visualize and interpret. In part, this may be attributed to the variety of formats in which numerical labelling can be presented,

e.g., per 100 g, per unit, per serving size, or other manufacturer-defined amounts not necessarily coinciding with public health guidelines^{128,129}. Third, popular reference schemes (e.g., in the USA and UK) are outdated because they reflect amounts that were customarily consumed before the current obesity epidemic^{26,38}. Finally, certain formats provide contradictory information, such as depicted serving sizes on cereal packages⁴⁸ that actually promote overconsumption⁵⁰.

In some countries food packaging guidelines on portion sizes are voluntary and are issued by different industry bodies¹⁰¹. Given that consumers may distrust industry motives around portion size¹³⁰ and that visual information on the food package itself may be more impactful than text-based information¹³¹, the effectiveness of portion-size information delivered via food labels is difficult to predict. For example, two studies^{49,96} explored the effects of mandatory changes in portion-size information provided by the US FDA Nutrition Facts Panel, and found contradictory results. The first study concluded that, compared with existing labels, consumers who viewed labels with larger 'suggested servings' believed they were portioning out more calories in a virtual on-line experiment, and when tested in the laboratory, this led to reduced consumption of a snack⁹⁶. In the second study, a label indicating larger portion sizes led participants to serve 27% to 41% more snack to themselves and to others, suggesting that the amended food label promoted overeating⁴⁹. Confirming the importance of these labels, 78% of another group of 101 participants in this study claimed to understand that the Nutrition Facts label can be used as a guide to promote healthy portion control⁴⁹.

Providing serving size recommendations reflecting *smaller* rather than larger portions may work better. In one study 100 women were asked to taste and eat pizza *ad libitum*. Smaller meals were consumed when they were told that the pizza contained "4 servings", as opposed to "2 servings" (or no label) and the reduction was comparable to the effect of providing a smaller portion with no label¹⁷. Such information though needs to be specific. For example, providing only categorical size estimates (i.e., "small", "medium", "large" portion)

may be confusing because certain descriptors can result in a belief that less food has been consumed^{132,133}.

Overall, the results of these individual studies suggest that portion-size information provided either as part of a nutrition label, or when sold at food outlets, may be understood as normative information and has the potential to influence portion-size selection and intake. However, differences in study design have the potential to change the direction and magnitude of this effect (as suggested in a recent SR²⁸, and in particular when different reporting standards are used). Two of the aforementioned studies^{40,41} (conducted in a basketball event and a school canteen), and two on-line studies^{49,96}, found that the food label or depicted portion size on a pack increased both the portion chosen and the perceived amount selected of a meal/snack. However, testing the same label formats in the laboratory resulted in smaller consumed portions of candy in one of the same studies⁹⁶. Overall, controlled studies tend to find an impact of the format of portion-size labelling. However, these studies are overrepresented in comparison with field studies, which show varying effects.

For foods with packet labelling, recommendations include addressing the layout of the labels to correct serving-size inconsistencies, to reduce complex information, to avoid the need for serving-size calculations, and to consider consumer literacy and numeracy (e.g., per 100 g or mL *alongside* serving size, household measures, and number of servings)^{51,132}. In terms of FOP label information, efforts should be made to present meaningful serving-size units that can be easily conveyed, and complicated layouts should be avoided¹³².

Modified tableware

Several studies, including various meta-analyses^{3,40,52}, have explored the effects of modified tableware. The first meta-analysis (involving 15 comparisons) found no effect of dishware size (plates and bowls) on energy intakes⁵². However, a wider review including 19 comparisons of tableware reported a small-to-moderate effect on portion selection and

intake after changing the size or shape of plates, bowls, cutlery, or glasses³. A more recent meta-analysis involving 56 comparisons⁴⁰ concluded that the effect of modified tableware depends on how the portion size is determined – smaller plates lead to smaller meals, but only when the portion is self-served. The authors concluded that halving plate size led to a 29% reduction in the amount of food self-served and consumed. However, participants may have been aware that they were being monitored and it is possible that an awareness of the objective of the studies (demand characteristic) contributed to this effect.

Holden et al.⁴⁰ also looked at the relative effects of manipulating area (e.g., smaller plate) vs volume (e.g., smaller bowl), and whether amounts consumed or selected depended on whether food was served from or eaten directly off, the item. Manipulations to bowls and plates generated similar results when looking at consumption and selection studies together, i.e. the effect of size reduction occurred irrespective of whether area or volume were manipulated (SMD of 0.24 for plates vs 0.51 for bowls, with overlapping C.I.'s) and of instrument purpose (using a consumption vs a serving plate). However, when explored separately, the effect of larger bowls on consumption was larger than for larger plates ($d=0.47$ vs $d=0.06$ for actual intake, and $d=0.79$ vs $d=0.49$ for intended intake, Table 2, Holden et al.'s study). Previous reviews have also concluded that manipulations to bowls has a stronger effect than manipulations to plates^{52,134}. However, these results may be confounded by demand characteristics, and some observations were taken in the presence of distractors and/or with fixed portions^{40,134}. Observations may also be further moderated by BMI, because overweight participants are likely to select smaller portions for social desirability reasons⁹⁵. A more recent study¹³⁵ considered the impact of different plate sizes on expected satiation and expected consumption in overweight and lean adults. The authors found that a smaller plate generated higher expected satiation and lower predicted intake, but only in lean participants. Age and gender do not appear to have a strong influence on tableware effects⁵².

Findings relating to the manipulation of utensils are inconclusive. In an uncontrolled study, Geier et al.¹³⁶ found that people passing by an apartment lobby consumed more free candy when a large spoon was placed next to the bowl, compared with a regular spoon. However, an intervention¹³⁷ exploring fork size in adults showed that a small fork leads to larger meals in a restaurant setting (maybe because the small fork does not give diners the same feeling of making progress in satisfying their hunger as the large fork does, and so they continue to eat for longer). In children the effects of spoon size appears to influence amounts self-served, but not consumed¹³⁸. A further study¹³⁹ found that using tongs (replacing spoons) reduced self-served portion sizes by 16.5% at a worksite salad bar, but only 'unit size' items (e.g., cherry tomatoes) were measured.

Studies looking at the use of bottles and glasses of varying shapes suggest that perceptual effects are likely to play a role in portion choice^{140,141}. Overall, wider and shorter containers (as opposed to narrower and taller containers) lead to worse estimation of volume, more liquid poured, and more consumed¹⁴². Beyond the effect of container and participant characteristics, similar confounds identified for the tableware studies may apply. For instance, some studies were conducted at social events, while others were conducted under laboratory conditions, which may have affected the extent to which participants were aware that their food intake was being monitored^{140,143}. Across these studies, different samples were recruited, including; normal weight adults, overweight children, and adults attending a weight-loss programme. These groups are likely to have different eating habits and attitudes to food, which may explain variability in study outcomes¹⁴⁴.

Results are more consistent when calibrated plates have been used^{41,53,54}. Calibrated (also known as partitioned or portion-control) plates represent a more direct intervention for portion control than reduced-size utensils as they usually depict portion size information or provide a clear guide indicating how much of the plate should be allocated to individual food groups (some examples can be found on-line, e.g.^{145,146}).

Weight-loss interventions incorporating these tools have shown promising results, although in some successful cases^{53,54} the tools have been deployed alongside dietetic counselling and other intervention components, making it difficult to isolate the role played by a portion-control tool. For example, in a study of patients with type 2 diabetes, a calibrated diet bowl for cereals and soups, together with a plate marked with sectors for 3 food groups, resulted in greater weight loss (2 kg) than that in a control group, over a 6-month period⁵³. Similar results were achieved using a sectored plate and calibrated bowl as part of a dietetic weight-loss intervention over a 3 month period⁵⁴, and as part of a 6-month tele-coaching intervention⁵⁵. Differences by sex were observed in some studies and in many cases the intervention failed to show efficacy beyond 3 months, suggesting lack of adherence. Only two studies have explored the effectiveness of a portion control plate on its own. In one study⁴¹ 29 people with obesity used a portion-control crockery dish and bowl (made of baked clay), and a calibrated glass, at home. Over a two-week period participants reported that they found the plate easy to use and that it helped to control portions of starch and to increase portions of vegetables. In a second study⁵⁶ 110 university students (normal weight) self-served portions onto either a portion-control plate or a larger dinner plate, and followed instructions based on two USDA guidelines (ratios or absolute amounts). Compared with the larger plate, the portion-control plate reduced self-served amounts in all conditions but did not promote increased intake of vegetables (portions remained below recommendations). While both studies suggest a potential positive role for portion-control plates *per se*, their sustained benefit remains unclear. Together, these experiments highlight the need for more research and in different populations, including children and the elderly.

The use of other calibrated utensils (e.g., glasses and serving utensils) has been explored, but to a lesser extent. In the study exploring the acceptability of the calibrated crockery plate⁴¹, a calibrated glass and bowl were also included. However, of these, participants perceived the glass as less helpful⁴¹. In the same cross-over study participants were also offered calibrated serving spoons for starch, protein and vegetables, which they found

equally acceptable and a helpful tool, both to reduce portions of starchy foods and to increase the selection of vegetables and salad. However, these data were self-reported and their sustained effect on food choice and energy intake remains unclear.

The underlying mechanism(s) by which modified tableware impacts food intake also remains unresolved. One suggestion is that the perceived size of food portions becomes distorted by the size of the dish on which it is served. One example of this distortion is the Delboeuf illusion and is often illustrated using abstract circular shapes. Briefly, the size of a circle is perceived to be relatively larger if the gap between the edges of the circle and a second outer circle is small. Since the gap between food and the edge of a small plate is also small (relative to a larger plate), it is possible that distortions to food-portion estimation occur for the same reason¹⁴⁷. Such illusions may bias both serving size and consumption, and have the potential to promote overconsumption^{147,148}. Similarly, for liquids, studies suggest that larger and curved glasses impair the ability to estimate volume^{149,150} (participants consistently pour a larger volume into wider and shorter glasses than into narrower and taller ones, and drink more slowly from a straight glass than a curved glass^{141,151}).

As for calibrated plates and serving utensils, it is possible that these tools may prompt users to pay additional attention to self-served portions of individual meal components relative to the whole meal, mediated by visual information on the appropriate amount to be consumed. This may induce a recalibration of their normative beliefs about appropriate portion size (see below under individual level strategies). Evidence has shown that this *portion-norm recalibration* is possible for meals consumed under laboratory conditions already at the first exposure, at least in lean subjects eating a specific meal (quiche)¹³. An ongoing study is exploring whether a similar effect can be achieved in overweight individuals using a portion control plate, and whether visual attention plays a role in this process¹⁵².

Age-appropriate tableware has also been advocated for children, including the use of smaller plates and plates with rims¹⁴⁸. This suggestion is based on observations that adult-size plates encourage children to self-serve more of the foods they like, possibly by biasing

their perception of physical size or by altering normative beliefs about appropriate portion size¹⁵³. Nevertheless, it should be noted that the effect of serving food on smaller plates in children is not reliably demonstrated¹⁹, and although the presence of rims appears to reduce the Delboeuf illusion, there is little evidence that rimmed plates reduce food intake¹⁵⁴.

Overall, the current evidence suggests that reducing the size of plates and especially bowls, and providing taller and narrower glasses, may help to reduce intakes of self-served portions. However, when amounts are pre-plated rather than self-served then reductions in intake are less likely to occur. The use of calibrated utensils has yielded promising results, but more research is needed to demonstrate sustained changes in energy intakes.

Palatability, food satisfaction, and expected satiety

Recently the role of sensory attributes and, in particular, their contribution to food palatability and food satisfaction, has been proposed as an important determinant of food intake and satiety^{42,97,155,156}. This view stems from research suggesting that food enjoyment directly impacts appetite and cravings, which in turn can impact portion selection, food intake and body weight¹⁵⁷, and may motivate other health behaviours^{59,158}. Recent studies also suggest that *food satisfaction* (defined as a generalized appreciation of food beyond just taste)¹⁵⁹ plays an important role in governing food intake⁹⁷, to the extent that vividly imagining the sensory experience of preferred foods leads to the selection of smaller portions⁵⁹. Indeed several studies have shown that enhancing the sensory properties of equally liked iso-energetic drinks and small portions of breakfast foods leads to increased satiety and reduced energy intakes^{57,155,160}. Enhancing the expected palatability of a food also impacts selection and potentially consumption. For example, labelling the same vegetables with indulgent descriptors (e.g. “Zesty ginger-turmeric sweet potatoes”) increased the number of people choosing them and the total mass selected in a university canteen compared with basic (“sweet potatoes”) or healthy labels (“cholesterol-free sweet potatoes”, “wholesome sweet potato superfood”)¹⁶¹. Merely increasing the portion size of low energy-dense foods (typically less palatable) and excluding high energy-dense (palatable) options is unlikely to

be sustainable in the longer term as food satisfaction is a primary driver of food choice and intake^{19,162,163}.

Recent functional magnetic resonance imaging studies have also shown that compared with regular diets, monotonous diets induce stronger cravings for liked foods (which are typically energy dense), potentially leading to overeating (reviewed in⁹⁷). While the effect of liking is relatively robust, it is difficult to modify because it relates to individual food preferences, which are highly heritable^{164,165}. In addition, if the volume of these foods is reduced then this may become obvious, promoting consumer dissatisfaction¹⁶⁶, and the potential for subsequent compensatory eating to occur¹⁶⁷. Consistent with this hypothesis, the effect of lower energy density on subsequent food-intake compensation is reduced when visual and sensory cues are removed^{168,169}. Therefore, sensory modification may provide a way to reduce energy intake without the need to reduce portion size – specifically, by lowering energy density, while preserving palatability and by limiting compensatory eating behaviour by maintaining satisfaction.

Despite palatability being regarded by many as a primary driver of food choice and energy intake^{162,163}, other variables also merit consideration¹⁷⁰. An important component of food satisfaction is food-related expectations¹⁵⁹. Foods differ considerably in their 'expected satiety' (the extent to which foods are expected to stave off hunger when compared on a calorie-for-calorie basis)⁸⁶. For example, one study showed that 200 kcal of pasta is expected to deliver the same satiety as 894 kcal of cashew nuts¹⁷¹. Related studies also show fine discrimination between foods – in one study simply changing the viscosity of a yogurt drink increased its expected satiety¹⁷². Although palatability is an important predictor of choice, expected satiety also plays a role, but especially when smaller portions are offered¹⁷³. Moreover, across typical lunchtime meals, variation in expected satiation (expected fullness) can be an even better predictor of portion selection (foods with low expected satiation are selected in larger portions) than variability in palatability¹⁷⁴. Together,

these findings illustrate opportunities to promote the selection of foods in smaller portions and to promote decisions that are not based solely on palatability.

Related studies have also shown that expected satiation is learned over time¹⁷⁵. In particular, expected satiety and expected satiation are found to increase as food becomes more familiar^{176,177}. This evidence for 'expected-satiation drift' may benefit the development of reformulated lower-energy-dense products that are designed to reduce energy intake. Once an expectation has been acquired, it tends to remain stable, even after repeated exposure to a lower-energy-dense reformulated version of a similar product¹⁷⁸.

In summary, recent research highlights palatability and food satisfaction as important determinants of food intake. In future this understanding might be leveraged to inform the design of reformulated weight-management food offerings that are enjoyed by consumers and that maximise the reduction in energy intake that can be achieved in this context.

Individual level strategies

The consumption of larger portions is governed both by the widespread availability of large portions and by financial incentives that promote their selection²⁵. This section provides a review of individual level strategies that might mitigate these pressures, including: reducing eating rate and bite size, changing plate cleaning tendencies, and manipulating portion-size norms and mindsets^{18,78} (see **Table 1** for overall summary and supplementary **Table S2** for specific study details). It is also worth noting that, unlike food-level strategies, which are passive, the effectiveness of individual strategies, especially in the long-term, depends on active engagement by the person. Much of the evidence discussed below comes from laboratory studies where participants receive instructions and are able to alter their eating behaviour (e.g. *eat more slowly*, *eat for health*, etc.). Evidence of individuals actively sustaining such behaviours under free-living conditions is much scarcer).

Eating rate and bite size

Eating rate (eating speed) and bite size (amount loaded on the fork/spoon, or for liquids, amount sipped), are inherited, yet trainable, eating traits, which have been shown to be tightly linked with energy intake and energy balance^{60,61,179}, and are associated with BMI¹⁸⁰ and fat mass⁶⁵. Among both adults and children, faster eating rates are produced by taking larger bite sizes that, in turn, are chewed less, leading to reduced oral exposure time^{181–183}. Although faster eating rates have been shown to have a heritable component¹⁷⁹, these behaviours are strongly influenced by food texture^{181,184} and portion size^{64,185}. Recent research indicates that larger portions induce larger bite sizes and quicker eating rates in overweight individuals^{64,185}, resulting in a reduction in oral exposure time⁶⁴. When food spends less time in-mouth this may reduce sensory-specific satiety (the decrease in pleasantness for a food previously eaten¹⁸⁶), which may lead to the consumption of larger meals¹. These findings are supported by a large body of literature suggesting that specific food-related perceptions play an important role in determining portion size⁴, alongside sociodemographic and psychological variables¹⁸⁷.

Portion size and eating rate may also interact in other ways. A recent study with pre-schoolers showed that children who ate at a faster rate consumed more calories. However, of these children, those who also selected a larger portion consumed significantly more calories, indicating that portion size and eating rate combine to have an additive effect on meal size and food intake (McCrickerd *et al.* unpublished data). At the food level these variables can also be manipulated to moderate meal size. Manipulations to the texture of a food can encourage a slower eating rate and this has been shown to moderate energy intake within a meal, as people tend to naturally take smaller bites and extend their chews *per* bite when texture is enhanced^{181,183}. In a recent study, combining texture-based reductions in eating rate with smaller portion sizes produced a 11-13% reduction in food weight and energy intake, compared with thinner versions of an *ad-libitum* meal⁵⁷.

Although changes in eating speed have the potential to reduce meal size, in turn, this might generate a more rapid return of hunger. However, some research suggests that reductions in portion size do not increase perceived hunger^{12,66}. Also, reducing energy intake by slowing eating rate does not appear to reduce perceived fullness at the end of a meal⁶⁰, and may indeed contribute to increased fullness in the inter-meal period. In agreement with this, some studies have reduced the eating rate of a meal by increasing the number of chews *per* bite and demonstrated an increase in post-prandial satiety *per* kcal consumed, alongside higher GLP-1, PYY and a longer suppression of ghrelin following extended chewing^{62,63,188–190}. Studies where eating rate has been trained for a sustained period of time show effects on weight loss^{61,191}. Whether reducing portion size in tandem with reductions in eating rate can support sustained decreases in energy intake without affecting hunger over longer periods has yet to be demonstrated. Similarly, whether reducing portion size leads to a concurrent reduction in eating rate over time remains unclear.

Overall, these findings suggest an opportunity to reduce the risk of increased energy intake from the portion-size effect by manipulating the rate of energy intake at a meal. In addition, manipulating these parameters may support reductions in energy intake by promoting greater feelings of fullness in the inter-meal period.

Modulation of plate cleaning tendencies

'Plate cleaning' refers to the tendency to consume everything on a plate during a meal. It is associated with increased body weight and has been proposed as a risk factor for overweight and obesity. It is also associated with being male and gaining higher educational attainment⁷². Although the methods for establishing these associations have been debated¹⁹², the prevalence of plate cleaning is often reported to be high (>90%)⁷⁰. Plate cleaners may be especially likely to overconsume when they receive large meals and this may place them at greater risk of diet-related disease⁶⁹. Plate cleaning does not seem to be influenced by exposure to larger portions though, at least in women⁶⁷. Given this, and the absence of a clear causal association between plate-cleaning and adiposity, the

implementation of public-health strategies to modify this behaviour would not seem justified at present. On the other hand, the presence of “leftovers” might reduce perceived consumption and the motivation for later compensatory behaviour⁶⁹. Research has shown that providing a leftover box to take home has the potential to reduce the portion-size effect⁶⁸. This simple approach may prove more successful than attempts to change plate cleaning tendencies that may have been established during childhood.

Recalibration of personal norms

A *norm* is defined as a belief about what constitutes a typical behaviour in a given situation, and is found to influence how people usually behave¹⁹³. It is now well established that portion-size norms influence food intake⁷³ – they represent beliefs and opinions on how much is considered appropriate, either personally (personal norms), or by others in a social context (social norms)⁷⁵. Personal norms for portion sizes are significantly larger in people with obesity than in normal weight individuals. They also play a greater role in men, in restrained eaters (those attempting to restrict food intake to control body weight), and in those with higher liking for a food.⁷⁵ Exposure to large portions may induce an adjustment or recalibration of these normative beliefs about appropriate portion size^{76,110}. Such processes may work via a mechanism of *anchoring* and adjustment to larger volumes, by which the size of a presented portion works as an anchor (reference for how much to eat) that strongly influences consumption and becomes the ‘norm’⁷⁴. Studies have shown that, under controlled conditions where participants make hypothetical decisions, brief visual exposure to large portion sizes may induce a recalibration of what constitutes an appropriate portion size⁷⁶. Whether the effects can shape the selection of unrelated foods and over long periods remains unknown. In response to some of these questions, Robinson and Kersbergen¹³ recently conducted three experiments with lean adults (75 to 124 men and women), exposed to two portion sizes of a quiche-based meal that was presented in either a typical or a markedly reduced (but still acceptable) portion size over 1 to 7 days. In the short term (next day), exposure to the small portion (100 g, 220 kcal) produced a reduction in intake of 100

kcal in women and 207 kcal in men. The same trend was observed after exposure over 7 days but the reduction in intake was no longer statistically significant. Overall, these results highlight the modifiable nature of portion-size perceptions and suggest that normative portion size judgements may be modifiable over very short periods but may be less likely to remain over longer durations. Further research is needed to establish whether beliefs can be modified in people who typically choose large portions and whether this approach offers promise as an intervention to aid weight loss.

Research has shown that parental portion size norms may also be important. Parents who serve their child based on their own beliefs about how filling a food is rather than on their child's appetite may be at risk of overserving and stimulating higher intake⁷⁷. Consistent with this observation, parental beliefs about appropriate portion size predicts their child's BMI, whereas their children's beliefs about portion size does not¹⁹⁴.

In summary, recalibration of personal portion-size norms towards smaller portions holds promise as a way to promote the acceptance of downsizing strategies. However, more evidence is needed before stronger conclusions can be drawn.

Cognitive strategies

Cognitive strategies, such as portion-size education, are common elements in many weight loss interventions. However, very few interventions have investigated improved portion control as a main outcome¹⁸. Such strategies cover a range of approaches, including purchasing (e.g., driven by impulse or cues such as promotions)⁷⁹, measuring skills, stockpiling, food exposure and unplanned eating, mindfulness and attention, out-of-home eating, and portion control self-efficacy awareness. Together, these strategies have been shown to be effective in decreasing BMI at 3 months⁷⁹ and in reducing body weight at 6 months, when deployed alongside an increase in physical activity⁸⁰. However, they tend to involve intensive educational components that participants need to integrate into their daily routine. A recent randomised controlled trial¹⁴ examined the effect of portion-size training in 186 women, using either portion tools (food scales, measuring cups/spoons and two image-

based educational aids), pre-portioned packaged meals, or standard dietary advice. All participants were experienced dieters who regularly self-monitored their weight, diet, and walking, and were offered regular contact with the investigators. Initially, participants receiving portion-control strategies showed greater weight loss. However, in the period following the intervention these differences disappeared and those who received a portion-control strategy were faster to regain weight¹⁴.

Other studies have considered the relative effectiveness of portion controls in people who adopt different dietary strategies. For example, studies have assessed people who adopt flexible, fixed, powerful or powerless attitudes, and those who eat attentively or unconsciously. Two individual differences are discussed below.

Psychological mindsets are defined as orientations that affect how consumers encode, interpret, and respond to information⁸⁷. Mindsets can be interpreted as a “lens” through which individuals assess their environment and make decisions, for example with a fixed (unchangeable) approach, a powerless approach, or a promoting approach. Mindsets can shape people’s eating behaviour, including their control of portion size, affecting how they respond to failure to adhere to a diet and how they start making changes to control portion size⁸⁷. Mindsets may even influence hormonal responses to food exposure⁸³. A recent fMRI study⁸⁴ has shown that manipulating a person’s mindset to eat for health or pleasure at lunch, as opposed to fullness, can reduce the size of selected portions (using a virtual portion-selection task), and that this is correlated with activation of brain areas related to self-control. In contrast, asking the participant to select a portion size for fullness resulted in larger portion size selections and the activation of brain areas related to the processing of interoceptive signals (i.e., being aware of being full).

A person’s mindset around social status can also influence their valuation of calories, their selection of portions, and their food intake^{104,195}. In two studies^{81,196} participants received feedback that temporarily decreased their perceived social status. Subsequently, their calorie estimation and ability to detect energy differences in foods worsened, and their

calorie selection, desire for the food and intake at an *ad-libitum* meal increased. A third study¹⁹⁵ confirmed that inducing feelings of powerlessness via a virtual manipulation (on-line experiment) as well as through field interventions (banner displayed in a building hall), results in choosing larger portion sizes of free food. Overall these results suggest that if this type of mindset persists, then the psychological experience of low social status may reduce the efficacy of portion size interventions.

Eating inattentively or while distracted (sometimes referred to as *mindless eating*) has also been associated with poor portion control¹⁸. One possibility is that distraction impairs the ability to accurately estimate amounts of food consumed and might influence the capacity to make deliberate decisions about how much to eat^{18,78}. Memory and in particular food-related episodic memory has also been implicated in meal-size selection⁸⁶. A meta-analysis by Robinson *et al.* (2013)⁷⁸ suggests that distraction during eating increases meal size and that distraction also impairs 'memory for recent eating' leading to greater intake at a subsequent meal (Table 2, **Figure 1**). Although a recent study failed to replicate this finding⁸².

Population level strategies

Population level strategies concern those that are either able to be directly applied simultaneously to, or that are feasibly scalable to, whole populations. Interventions to change human behaviour can be broadly categorised as structural (i.e., changing the environmental context in which an individual behaves) or agentic (i.e., approaches targeting the individual and their knowledge or skills to make healthier choices). While both may play a role in a successful public health strategy, the scalability of agentic approaches may be limited by the underlying resource that might be required to support their administration and execution. That said, some agentic interventions have been implemented effectively at scale¹⁹⁷, including weight loss and smoking cessation programmes, while others, such as nutritional labelling, require only the provision of information. The sections that follow consider the potential impact of population-level approaches that target changes to the

physical, sociocultural, economic and political environments that influence food selection and consumption (see **Table 1** and Supplementary **Table S3**).

Physical environment

Changing aspects of physical environments ('nudging') has been proposed as a useful population-level strategy to improve patterns of intake^{29,198}. Environmental cues fundamentally shape dietary decisions and behaviours, potentially outside conscious awareness^{26,199}, and so changes to the physical environment have the potential to confer benefits to health²⁰⁰. The TIPPME intervention typology (Typology of Interventions in Proximal Physical Micro-Environments) attempts to categorise specific ways in which the physical environment can be altered, and includes 'size' interventions, defined as "*Altering size or shape of products or objects*", thus including food²⁰¹. Food-level interventions that involve altering the size, shape or presentation of foods could therefore be considered examples of nudges where they are scaled-up and administered at a population level. For example, reducing or limiting portion sizes represents a particularly feasible and scalable approach when applied to pre-packaged or processed products that are manufactured and widely distributed to whole populations, but also in other environments where food is prepared from fresh on commercial premises (e.g., restaurants)^{90,91}. Manipulations to food product order or proximity can also influence food choice and may represent another environmental approach²⁹, for example by moving larger portion sizes further away or making smaller sizes more accessible (**Table 1**). However, sustained environmental interventions are challenging, they require coordination between a range of stakeholders (e.g., policy makers, food manufacturers, and restaurant owners), and they need to be regarded as acceptable by the public²⁵. In particular, reductions in portion size are likely to face more resistance than other public health strategies, such as calorie labelling and banning soft drinks from schools²⁰². Some of these issues are discussed in more detail below.

Educational and social environment

In general, educational and social marketing campaigns^{22,37} have had a small impact on population behaviours. This may be because social norms about eating may be difficult to change. Social norms are implicit codes of conduct that provide a guide to appropriate action²⁰³. Social norms around eating impact both food choice and amounts consumed, perhaps by altering self-perceptions and/or the sensory/hedonic evaluation of foods^{73,203}. A meta-analysis of 15 studies⁷³ showed that providing 'normative information' suggesting that others make low-energy or high-energy food choices significantly increases the likelihood participants will make similar choices. Providing normative information about appropriate portion size might also be effective⁷⁵, but this is yet to be demonstrated, and the effect this might have on sub populations (e.g., stratified by gender and BMI), remains unclear.

Economic environment

Increased sales translate into increased usage, caused by driving an increase in either the amount per serving (portion size), or the frequency of consumption²⁰⁴, or both. In many cases, the appeal of larger product sizes is enhanced when they cost relatively less than smaller product sizes by volume. 'Proportional pricing' would eliminate this incentive and might discourage the purchasing of larger portions for that reason. Such a change could reasonably be applied on a large scale, although there is a lack of experimental evidence examining the effectiveness of this strategy in isolation. A recent meta-analysis²⁷ found strong evidence that changes in price can influence both healthy and unhealthy food choices, although there was high study heterogeneity ($\geq 65\%$) (**Table 1**). In particular, subsidies for fruit and vegetables, healthy beverages and other healthy foods (22 comparisons) were associated with a 12% increase in intake per each 10% decrease in price. Taxation of fast foods, SSBs and other unhealthy food and beverages (15 comparisons) was associated with a 6% decrease in intake per each 10% increase in price. On the other hand, individual studies do not always show conclusive results. One intervention²⁰⁵ considered the impact of value size pricing and calorie information on fast-

food choices in 594 US regular consumers. Value size promotions (when the cost per unit is lower for the larger vs the smaller product) did not encourage the selection of larger (kcal) meals. In a second study²⁰⁶ portion-size choices were assessed in both a Dutch worksite cafeteria and a fast-food restaurant. Similarly, in two different promotion conditions, value-size promotions did not lead to the selection of larger meals, but for overweight customers, the proportional (non-promotional) pricing was beneficial (they tended to choose smaller portions). A third study¹⁶⁷ examined the impact of proportional pricing of small- and regular-portion meals across 26 Dutch worksite cafeterias. The smaller portion (cheaper) was hardly taken up and did not affect food choices. In a fourth study⁸⁹, 245 mostly overweight US adults were randomised to an on-line menu choice task that enabled orthogonal contrasts across four different conditions - portion size (half vs full), calorie information (absent vs present), healthiness (healthy vs less healthy entrée), and price (linear vs promotional). In the presence of calorie information, removing the promotion led respondents to choose more calories from healthy entrées but had no impact on portion choice (participants preferred to stick to a full portion and to change meal content rather than switching to a smaller portion of the unhealthy dish, perhaps reflecting a portion-size norm).

Together, these results suggest that financial strategies have the potential to improve portion choice (especially increasing portions of foods and vegetables), however they may have a weaker effect on portion control for other foods especially when they go unnoticed or when their impact on cost is marginal. Moreover, using proportional pricing may interact with other factors affecting consumers' decisions, such as portion norms or motivation to lose weight. Generally, consumers are supportive of removing value pricing from restaurant food offers²⁰⁷ and given existing methodological limitations and overall lack of data, this topic merits further investigation.

Public health policy

Reductions in portion size might be implemented on a voluntary basis. However, historically this has proved largely ineffective. For example, the Public Health Responsibility Deal in the

UK²⁰⁸ encouraged industry entities to enter into voluntary public-private agreements with government to improve public health in the areas of food, alcohol, health at work, and physical activity. Subsequent evaluations suggest that this failed to effect a meaningful change in diet and this was attributed to poor implementation and a reliance on ineffective means of changing behaviour (such as only providing information, see **Table 1**)⁹³. This is unsurprising given that public health is not a central priority for many commercial enterprises and because competitive advantage may be lost if voluntary changes are made by some but not all organisations²⁵. Therefore, regulatory and legislative approaches may be more effective (the removal of trans-fats illustrates this point²⁰⁹).

Based on the existing evidence, Marteau et al.²⁵ proposed that some of the most effective policies may be those that target the availability and accessibility of large portion and package sizes in stores and cafés. This includes packaging cues (i.e., demarcation or segmentation cues), size of tableware in self-service and served foods/drinks, and the removal of value pricing on large portions and package sizes. However, further high-quality evidence is needed before these and other policy changes are likely to be considered. To achieve this, researchers need to explore portion-size manipulations in real-world settings. This may be possible in small-to-medium size environments (e.g., restaurants^{90-92,167}) but may be less feasible in larger-scale contexts (e.g., large supermarket chains), especially when interventions involve financial incentives. Here, alternative sources of evidence may be needed, including natural experiments, longitudinal designs, and comparisons between geographic areas.

Overall impact of portion size strategies

This review has examined the existing evidence supporting strategies that are currently advocated for reducing portion size and meal size at the individual, food, and population level (summaries in **Tables 1-2, Figures 1-2**).

Pooled data from 7 published systematic reviews including meta-analyses show that across strategies (22 meta-analyses), the highest impact on consumption was for modifying

bottle/glass shape or the size of the serving plate (**Table 2, Figure 1**). However, these were low quality studies and included a very small number of comparisons ($k=1-3$). The next most impactful strategies were modifying pack size, bowl size, removing distraction, and removing visual cues of foods eaten, however k still ranged from 4-16). The impact of modifying unit size, portion size offerings, eating rate/bite size, and normative beliefs about portion size tended to be of small to medium magnitude. The impact of the size of tableware (consumption plate, bowls mostly) was variable, with some utensils being more impactful than others and with study conditions also having an influence^{3,40,52}. Bowl size was more impactful than plate size on both actual and intended intake (**Table 2, Figures 1a, 1b**) but this was affected by whether the subjects self-served their portion or not and whether they were aware of the manipulation⁴⁰. Except for the serving plate comparison⁴⁰ and another analysis including 3 comparisons of bowl sizes⁵², the effect sizes of all tableware in general were of smaller magnitude than for other strategies, in particular for plates. The four more extensive meta-analyses^{2,3,40,60} ($k=86$, $k=24$, $k=58$, $k=27$) all showed medium effect sizes on consumption, for portion size offerings, eating rate/bite size, and tableware size. Meta-analyses examining intended consumption showed a larger impact for size of bowls and other tableware than for portion size offerings; however there was high heterogeneity and the magnitude of the effects tended to be small to moderate, with the exception of bowl size (**Figure 2**).

To complement the data from meta-analyses, a variety of randomised-controlled studies, observational studies, and narrative reviews have been considered, and a wide range of mediators of portion-size choice and intake have been discussed (**Table 1**). A central limitation of these data is that while many studies - increasing portion size leads to greater intake, there is a paucity of evidence showing that reducing portion size has the converse effect. In addition, whether changes in portion size are considered as reductions or increases depends on how the baseline is defined and this varies across studies. This stems from the problem that, at present, there is no objective or widely agreed 'appropriate' portion

size that covers the range of foods and meals that is available to consumers^{128,129}. This makes it difficult to compare the food portions used in different studies – in some cases they might be ‘larger than normal’ whereas in others the same or different foods might be ‘smaller than normal’¹⁴⁴. Further, what people regard as a normal portion is likely to vary across individuals and this variability might also be reflected in advice offered by health professionals and in government-sponsored schemes. In part, this uncertainty is also compounded by the increasing availability of larger portion sizes^{6,38,210,211}, a change that has occurred in tandem over the same period that much of the associated scientific literature has developed.

Other limitations include a dominance of laboratory-based and acute, as opposed to medium or long-term field studies, and the presence of confounders that may affect portion selection and intake, such as participants being aware that food intake is being measured^{40,143}. Studying the portion-size effect at the population level (where not everyone needs to reduce intake) is fundamentally different from testing interventions for weight loss. Also, aims in children differ from those in adults and recommendations will likely vary.

A final limitation is that assuming portion size reduction is an effective way to control population-level intakes, the extent to which reductions will be tolerated by consumers is unclear. From the current knowledge and consumer perspective^{46,166} a portion-size threshold is likely to exist, at least for some products. Whether these thresholds undermine strategies to reduce portion size is also unclear.

Overall, the potential impact of some food-level strategies, such as reducing the size of commercially available meals and snacks, and modifying packaging, is well documented. Also, food strategies are likely to be enhanced by individual-level strategies that modify eating behaviours (e.g., eating rate, bite size), norms, and cognitive approaches. However, the impact of both food-level and individual-level strategies is likely to be small and will not

be sustained unless implemented in combination with modifications to the environment, based on policy, financial, and marketing approaches^{14,21}. Looking ahead, an important challenge is the need for methods to assess the feasibility of implementing downsizing strategies at a large scale^{18,144} and across multiple sectors, including food retailers and manufacturers, restaurant owners, chefs, and the general public.

The challenges in developing effective portion reduction strategies reflect a limited understanding of cognitive and physiological determinants of portion control. In particular, it remains unclear how various food-level and individual mediators interact over long periods to influence behaviour and energy balance. Several questions should be given high priority, such as those related to food-level cues, which may help inform the design of better interventions at other levels. Studies that integrate individual subject-level differences with an assessment of food-related characteristics, meal eating behaviour, and cognitive processes are needed⁴. In controlled studies participant demand characteristics are a particular problem^{143,212} and efforts should be made to incorporate assessments of everyday consumer behaviours, outside the laboratory, and over long periods. In addition, studies that identify population segments who respond best to different interventions are needed so that interventions can be targeted to where they are the most effective.

Quality of evidence

A total of 72 publications were reviewed, including 8 meta-analyses^{2,3,27,40,52,60,73,78} and one umbrella review⁹³. For the majority of the meta-analyses, the quality of evidence was rated as low to moderate, when assessed through official systems (e.g. GRADE, AHA). Meta-analyses showing larger effect sizes tended to include more heterogeneous studies, studies of lower quality, or those that involved a smaller number of comparisons. Therefore conclusions from these studies need to be treated carefully³. For evidence not formally graded but assessed qualitatively, the quality of individual studies was generally described

as neutral to positive, based on study design, blinding, publication bias and whether participants were aware of the study purpose. Methodological differences are likely to affect study quality and the extent to which findings can be extrapolated to different eating contexts. For example, meals are complex and they vary greatly across studies, which might otherwise account for different outcomes across settings and populations.

CONCLUSIONS

A wide range of portion-reduction strategies and potential targets have been reviewed, ranging from food-level approaches (strongest potential effects for modified commercial portion sizes and packaging, and some types of tableware) to individual-level (training of eating habits and recalibration of consumption norms), to population approaches (policy strategies involving structural changes in food production and distribution). For some (especially food and individual-level strategies) there appears to be acceptable evidence of a small to moderate effect. However, in isolation, none is likely to have a sufficiently large impact on population intakes to reverse the portion-size effect. In addition, while significant progress has been made in this field, much of the underlying evidence is provided by studies exploring the effects of large, rather than small, portion sizes, and from observations drawn from acute interventions conducted in small-scale laboratory settings. Wider changes to the portion-size environment will be necessary to support effective individual and food-level strategies. In particular, appropriate changes are needed that enable consumers to be satisfied with “less” at an appropriate price-point, in a way that sustains the profitability of smaller portions for food manufacturers and retailers.

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FIGURE LEGENDS

Figure 1. Effect sizes reported in meta-analyses of strategies to reduce actual intake by strategy category (1a) and decreasing magnitude of effect size (1b). Each bar depicts the overall effect size \pm 95% CI for each strategy and corresponds to a separate analysis. Bars representing meta-analyses extracted from the same publication are filled with the same shade. A positive effect size represents an increase, and a negative effect size, a decrease in actual intake. The code after each strategy on the X axis (e.g. ZLA) corresponds with the code for each meta-analysis in Table 2. Afshin et al.'s meta-analysis could not be included due to differential metrics being reported. Quality of the evidence is indicated as follows: + = very low or low quality of evidence; ++ = moderate quality of evidence; no sign = quality of the evidence not systematically graded.

Figure 2. Effect sizes reported in meta-analyses of strategies to reduce intended intake, by strategy category. Each bar depicts the overall effect size \pm 95% CI for each strategy and corresponds to a separate analysis. Bars representing meta-analyses extracted from the same publication are filled with the same shade. A positive effect size represents an increase, and a negative effect size, a decrease in actual intake. The code after each strategy on the X axis (e.g. ZLA) corresponds with the code for each meta-analysis in Table 2. Quality of the evidence is indicated as follows: + = very low or low quality of evidence; ++ = moderate quality of evidence; no sign = quality of the evidence not systematically graded. The number of comparisons included in each meta-analysis are indicated with *k*.

1 **Table 1. Overview of current evidence on the impact of food, individual and population level strategies on portion size awareness, amount**
 2 **selected (intended intake) or actual intake.** Meta-analyses with overlapping studies are included if the total number of studies differs. Individual studies are
 3 included only when not included in previous reviews or meta-analyses. Studies including experiments addressing more than one strategy are included under
 4 each of the corresponding strategy category. Timeline defined as acute (1 day), short term (1 week), medium term (2-3 weeks), long-term (4+ weeks).
 5 Number of publications included in meta-analyses are shown in brackets and bold type. Quality of the evidence is presented on Table 2 (for Meta-analyses
 6 only). Full details of all studies are given in **Supplementary Tables S1-S3.** *Abbreviations:* A, highest evidence level category (see footnote a); B-D, second to
 7 fourth evidence level categories (see footnote a); ED, energy density; M, Meta-analysis or systematic review; PCM, portion controlled meal; PS, portion size;
 8 R, narrative review or analysis paper; RCT, randomised controlled trial.

9

	Evidence level ^a				Mediators	Overall magnitude of effect or impact ^b	Timeline of studies
	M	A	B-D	R			
FOOD LEVEL STRATEGIES							
PS offerings							
Zlatevska et al. (2014) ² (27), Hollands et al. (2015) ³ (55)	√				Larger and smaller PS offerings, PCMs	Small, moderate or large for acute effects on actual and intended intake (e.g. actual intake: 9-13% less meal/protein; 87% more vegetables) ⁹⁰ ; small for longer term effects on selection (e.g. incomplete implementation of intervention ⁹¹)	Acute, medium and long term (3, 12 months)
Rock et al. (2016) ⁴³ , Rolls et al. (2017) ¹⁴ , Lewis et al. (2015) ¹² , Robinson & Kersbergen (2018) ¹³ , Reinders et al. (2017) ⁹⁰ , Hollands et al. (2018) ⁹¹ , Berkowitz et al. (2016) ⁹²		√					
Ordabayeva & Chandon (2016) ⁴⁴			√				
Pack and unit size/number							
Hollands et al. (2015) ³ (55)	√						
Brogden & Almiron-Roig (2011) ³⁸ , Almiron-Roig et al. (2013) ³⁹ , Van Kleef et al. (2014) ⁴⁵		√			Larger, medium and smaller packs/containers, unit size, unit number	Small to moderate effect on actual and intended intake	Mostly acute studies (some medium term)
Van Kleef et al. (2014) ⁴⁵ , Mantzari et al. (2018) ⁴⁶			√				
Ordabayeva & Chandon (2016) ⁴⁴				√			
Food label						Unknown (limited evidence) or varied effect (from increased to decreased consumption) on actual intake; no effect	Mostly acute laboratory studies (some cross-sect. and
Brown et al. (2018) ²⁸ (32), Bucher et al. (2018) ⁴⁷ (5), Almiron-Roig et al. (2013) ³⁹ , Tal et al. (2017) ⁴⁸ , Dallas et al. (2015) ⁴⁹ , Neyens et al. (2015) ⁵⁰	√	√			Larger and smaller PS info on label, PS contextual info on label, type of meal, larger PS image on pack, taste, nutrition		

^a **Type of evidence** based on American Dietetic Association Evidence Library criteria³¹: **A**=RCT, cluster randomised trial or randomised crossover trial; **B**=prospective or retrospective cohort study; **C**= non-R controlled trial, non-randomised crossover trial; case-control, time series, diagnostic, validity or reliability study; **D**=non-controlled trial, case study, case series, cross-sectional, trend, before-after or other descriptive study; **M**=meta-analysis or systematic review; **R**, narrative review.

^b **Effect** based on Cohen's d criteria³² for meta-analyses: *Small*, d≤0.2 small magnitude or clinical relevance (even if significant); *Medium*, d=0.5 medium magnitude or clinical relevance; *Large*, d≥0.8 significant effect of clinical relevance. For individual studies not reporting effect size metrics, the effect was judged by the magnitude of changes reported.

Tal et al. (2017) ⁴⁸ , Benson et al.(2018) ³⁰	√	and health information	of health or taste information on portion size selection (confounding effect of general health interest)	field studies)
Ordabayeva & Chandon (2016) ⁴⁴ , Klieman et al.(2018) ⁵¹	√			
Tableware				
Robinson et al. (2014) ⁵² (8), Hollands et al.(2015) ³ (58, 3) , Holden et al. (2016) ⁴⁰ (20)	√	Larger & smaller dishes, bowls and glasses, wider & shorter glasses, portion-calibrated plates, bowls and glass, knowing study purpose	Small, moderate or large for dishware on intended and actual intake (tends to disappear beyond 3 m). Large impact on intake for bottles/glasses	Acute, 3, 6 months
Pedersen et al. (2007) ⁵³ , Kesman et al. (2011) ⁵⁴ , Huber et al. (2015) ⁵⁵ , Almiron-Roig et al. (2016) ⁴¹	√			
Hughes et al. (2017) ⁵⁶	√			
Sensory effects, expectations				
McCrickerd et al (2017) ⁵⁷	√	Sensory and ED manipulations, aesthetic and symbolic value of food, perceived sensory pleasure, satiety	Small effect on actual intake (around 10%) ⁵⁷ . Impact on intended intake seen also in virtual experiments ⁵⁹	Acute studies
Cornil & Chandon (2016) ⁵⁸ , Cornil & Chandon (2016) ⁵⁹	√			
McCrickerd & Forde (2016) ⁴²	√			
INDIVIDUAL LEVEL STRATEGIES				
Eating rate/bite size				
Robinson et al. (2014) ⁶⁰ (22),	√	Modifications in eating rate, bite size, chewing rate	Small to medium effect on actual intake (45 g reduction in PS in 12 m RCT) ⁶¹	Acute, 12 months or cross-sectional
Ford et al. (2009) ⁶¹ , Li et al. (2011) ⁶² , Zhu & Hollis (2014) ⁶³ , Almiron-Roig et al. (2015) ⁶⁴ , McCrickerd et al. (2017) ⁵⁷ , Fogel et al. (2017) ⁶⁵	√			
	√			
Plate cleaning				
Rolls et al. (2002) ⁶⁶ , Sheen et al. (2018) ⁶⁷ , Zuraikat et al. (2018) ⁶⁸ , Krishna & Hagen (2018) ⁶⁹ , Fay et al.(2011) ⁷⁰ , Hinton et al.(2013) ⁷¹ , Robinson et al. (2015) ⁷²	√	Effects of gender, BMI; presence of left-overs on plate-cleaning tendency	Null to small effect on actual intake (PS effect blunted by 47 g or 71 kcal for each 100 g of additional food eaten in a meal) ⁶⁸	Acute, cross-sectional
	√			
Portion size norms				
Robinson et al. (2014) ⁷³ (5)	√	Gender, BMI, PS anchors, perceived impulsivity, perceived appropriateness, food-related emotional conflicts, personal and social norms, parental influence, knowing purpose of the study, stakeholder priorities	Moderate effect, seen mostly for intended intake	Mostly acute (1 study short-term)
van Kleef E et al. (2014) ⁴⁵ , Marchiori et al. (2014) ⁷⁴ , Lewis et al.(2015) ⁷⁵ , Robinson et al. (2016) ⁷⁶ , Robinson & Kersbergen (2018) ¹³	√			
Ordabayeva & Chandon (2016) ⁴⁴ , McCrickerd & Forde (2016) ⁷⁷ , Marteau et al. (2015) ²⁵ , Robinson et al. (2013) ⁹⁵	√			
Cognitive strategies				
Robinson et al. (2013) ⁷⁸ (19)	√	PC strategies, physical activity, takeaway consumption, perceived deprivation, psychological mindset, pre-meal planning, previous food experience, episodic memory, food environment	Null to large effect on intended and actual intake (inconclusive effects for role of attention on later food intake) ^{78,82}	Acute, 3, 6 and 12 months
Poelman et al (2015). ⁷⁹ , Young et al. (2015) ⁸⁰ , Rolls et al. (2017) ¹⁴ , Sim et al. (2018) ⁸¹ , Whitelock et al. (2018) ⁸²	√			
Crum et al. (2011) ⁸³ , Hege et al. (2018) ⁸⁴	√			
Brunstrom (2011) ⁸⁵ , Brunstrom (2014) ⁸⁶ , Rucker & He (2016) ⁸⁷ , Steenhuis & Poelman (2017) ¹⁸	√			

POPULATION LEVEL STRATEGIES

Physical environment

Bucher et al. (2016)²⁹ (18)

√

Positional changes (distance, order) affecting immediate food intake or choice at individual level

Positive effect on food choice from closer position of foods however compensatory behaviour detected in some studies

Acute RCTs except for one long-term (9 months) longitudinal study

Educational and social environment

Robinson et al. (2013)⁷³ (5)

√

Croker et al. (2012)³⁷

√

UK Department of Health (2016)⁹⁴

√

Higgs (2015)²⁰³, The Marketing Society (2010)⁸⁸

√

Information about healthy/less healthy eating habits of others, individual traits (BMI, gender), programme adherence

Moderate effect of intake norms on food choice; low impact of public health campaigns on intakes for healthy/less healthy foods

Acute and long-term

Economic environment

Afshin et al. (2017)²⁷ (30)

√

Haws & Liu (2016)⁸⁹

√

Steenhuis & Vermeer (2009)²³, Vermeer et al. (2014)²⁴

√

Steenhuis & Poelman (2017)¹⁸

Price reductions (subsidies) and increases (taxation)
Promotional price and calorie label
Financial incentives in cafeterias and restaurants

Price reductions on healthy foods increased intake by 12% and price increases of unhealthy foods decreased intake by 6% for each 10% change in price²⁷; small overall effect when price incentive unnoticed, incentive too small, other concurrent factors e.g. calorie information given

Acute, medium and long-term

Policy^c

Knai et al. (2015)⁹³ (umbrella review of 17 reviews),

√

Marteau et al. (2015)²⁵

√

Synchronized action from policy makers, industry and the public, involving structural changes beyond information or awareness raising

Potentially moderate impact on selection and consumption if implemented at scale

Acute, medium and long-term

10

11

^c Includes analysis or review papers where portion size reductions are studied/reviewed and this is presented in a policy or population health context.

12 **Table 2. Effect size of strategies to reduce amount selected or consumed from the meta-analyses identified in this review.** Meta-analyses with
 13 overlapping studies are included if the total number of studies differs. I^2 for analyses including a single comparison ($k=1$) has been assumed as 0 when not
 14 reported. Intended intake includes portion size selection. Effect sizes are indicated as standardised mean differences (SMD), Cohen's d , or % change, based
 15 on each publication. $ES>0$ indicate increases and <0 decreases, in intake for the listed strategy. For details of individual studies see **Supplementary Tables**
 16 **S1-S3**. *Abbreviations:* AHA, American Heart Association; ES, effect size; GRADE, Grading of Recommendations Assessment, Development and Evaluation;
 17 I^2 , heterogeneity index; k , number of comparisons NA, not applicable, NR, not reported, USPSTF, US Preventive Services Task Force.

18

Strategy / Intervention	Authors (CODE)	Impact on ACTUAL intake			Impact on INTENDED intake			Effect size magnitude ^d	Quality of evidence
		ES (95% CI)	k	I^2	ES (95% CI)	k	I^2		
FOOD LEVEL									
PS offerings (larger)	Zlatevska et al. (2014) ² (ZLA)	0.45 (0.38, 0.52)	86	65%	0.18 (0.05, 0.31)	13	41%	Small to medium	MODERATE
	Hollands et al. (2015) ³ (HOL)	0.37 (0.26, 0.48)	58	NA	0.30 (0.09, 0.50)	5	NA	Small to medium	MODERATE (GRADE)
Pack and unit size or number (larger)	Hollands et al. (2015) ³ (HOL)								
	Pack size	0.54 (0.27, 0.80)	10	NA	NA	NA	NA	Medium to large	MODERATE (GRADE)
	Unit size	0.33 (0.07, 0.58)	9	NA	NA	NA	NA	Small to medium	MODERATE (GRADE)
Modified tableware	Robinson et al. (2014) ⁵² (ROB4) ^e								
	All smaller tableware	-0.18 (-0.35, 0.00)	15	77%	NA	NA	NA	Small	Not formally or systematically assessed, but limitations noted
	Smaller plates only	-0.06 (-0.24, 0.11)	11	64%	NA	NA	NA	Small	
	Smaller bowls only	-0.61 (-0.94, -0.29)	3	69%	NA	NA	NA	Medium to large	
	Hollands et al. (2015) ³ (HOL)								
	All larger tableware	0.29 (0.07, 0.51)	12	NA	0.51 (0.21, 0.81)	7	NA	Small to medium	MODERATE (GRADE)
	Shorter & wider water bottle	1.17 (0.57, 1.78)	1	0%	NA	NA	NA	Large	VERY LOW QUALITY (GRADE)
	Shorter & wider soft-drink bottle/glass	1.47 (0.52, 2.43)	3	90%	NA	NA	NA	Large	LOW QUALITY (GRADE)
	Holden et al. (2016) ⁴⁰ (HLD)								
	All larger tableware	0.35 (0.29, 0.41)	27	NR	0.51 (0.46, 0.56)	29	NR	Small to medium	Not formally or systematically assessed, but impact of being aware of study purpose tested
Larger plates only (area)	0.06 (-0.06, 0.18)	10	NR	0.49 (0.27, 0.71)	7	NR	Small to medium		
Larger bowls only (volume)	0.47 (0.39, 0.55)	16	NR	0.79 (0.57, 1.01)	10	NR	Medium to large		

^d **Magnitude** of effect size based on Cohen's d criteria³² for meta-analyses: *Small*, $d \leq 0.2$ small magnitude or clinical relevance (even if significant); *Medium*, $d = 0.5$ medium magnitude or clinical relevance; *Large*, $d \geq 0.8$ significant effect of clinical relevance.

^e For **laboratory studies**, overall effect size for all tableware was -0.06 (95%CI -0.24, 0.11, $k=11$, $I^2=64\%$) and for **field studies** -0.47 (95%CI -0.84, 0.09, $k=4$, $I^2=86\%$).

	Larger plater only (volume of serving utensil)	1.15 (0.15, 2.15)	1	0%	0.33 (0.22, 0.44)	12	NR	Large (actual intake), small to medium (intended intake)	
INDIVIDUAL LEVEL									
Eating rate/bite size (quicker/larger)	Robinson et al. (2014)⁶⁰ (ROB2)	0.45 (0.25, 0.65)	24	92%	NA	NA	NA	Medium	Not formally or systematically assessed, but no major limitations noted (from assessing blinding, randomization, participant awareness of aims, confounding, publication bias)
Portion size norms	Robinson et al. (2014)⁷³ (ROB3)								
	High intake norms	0.41 (0.20, 0.63)	11	47%	NA	NA	NA	Small to medium	Not formally or systematically assessed, but no major limitations noted (from assessing participant awareness of aims, assessing awareness of aims, control/comparator type, method limitations, publication bias)
Cognitive strategies	Robinson et al. (2013)⁷⁸ (ROB1)								
	Low intake norms	-0.35 (-0.59, -0.10)	8	56%	NA	NA	NA	Small to medium	Overall "high quality evidence"
	Distraction on immediate intake	0.39 (0.25, 0.53)	14	70%	NA	NA	NA	Small to medium	MODERATE
	Distraction on later intake	0.76 (0.45, 1.07)	6	0%	NA	NA	NA	Large	MODERATE
	Enhancing memory of foods eaten on later intake	-0.40 (-0.68, -0.12)	6	0%	NA	NA	NA	Small to medium	MODERAE
	Removing visual cues of amounts eaten on immediate intake	0.48 (0.27, 0.68)	4	59%	NA	NA	NA	Medium	Not formally or systematically assessed
	Enhancing attention on immediate intake	-0.09 (-0.42, 0.25)	2	0%	NA	NA	NA	Small	MODERATE
POPULATION LEVEL									
Economic environment	Afshin et al. (2017)²⁷ (AFS)^f								
	Taxation (per each 10% increase in price)	-6.01% (-7.83, -4.20)	15	65%	NA	NA	NA	Small to medium	MODERATE (Class II AHA, Grade B USPSTF)
	Subsidy (per each 10% reduction in price)	12.42% (10.16, 14.68)	22	99%	NA	NA	NA	Small to medium	STRONG (Class I AHA, Grade A USPSTF)

^f **Taxation** explored for fast foods, SSBs and other unhealthy food and beverages. **Subsidies** explored for fruit and vegetables plus other healthy food and beverages.