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The effect of food type on the portion size effect in children aged 2- 12 years: A systematic review and meta-analysis.

S Reale[1], J Hamilton[1], R Akparibo[1] M. M. Hetherington[3], J. E. Cecil[4], S. J. Caton[1*]

[1] Public Health, School of Health and Related Research, University of Sheffield, UK

[2] Health Economics and Decision Science, School of Health and Related Research, University of Sheffield, UK

[3] School of Psychology, University of Leeds, UK

[4] School of Medicine, Population and Behavioural Health Sciences, University of St Andrews, UK

*Correspondence: Dr S J Caton, School of Health and Related Research, Public Health, Regent Court, 30 Regent Street, Sheffield, S1 4DA

slreale1@sheffield.ac.uk; jean.hamilton@sheffield.ac.uk; r.akparibo@sheffield.ac.uk; m.hetherington@leeds.ac.uk; jc100@st-andrews.ac.uk; S.caton@sheffield.ac.uk

Abstract

Visual cues such as plate size, amount of food served and packaging are known to influence the effects of portion size on food intake. Unit bias is a well characterised heuristic and helps to determine consumption norms. In an obesogenic environment where large portions are common place, the unit or segmentation bias may be overridden promoting overconsumption of both amorphous or unit foods. The aim of this review was to investigate the impact of offering unit or amorphous food on the portion size effect (PSE) in children aged 2 to 12 years.

A systematic search for literature was conducted in Medline, PsycInfo and Web of Science in February 2018. A total of 1197 papers were retrieved following the searches. Twenty-one papers were included in the systematic review, of which 15 provided requisite statistical information for inclusion in a random effects meta-analysis.

Increasing children's food portion size by 51-100% led to a significant increase in intake (SMD=**0.47, 95% CI: 0.39 – 0.55**). There was no evidence to suggest that increases in consumption were related to food type (p= 0.**33**), child age (p=0.**47**) **or initial portion size served (p=0.14)**. **Residual heterogeneity was not significant (p=0.24).**

The PSE was demonstrated in children aged 2 to 12 years when offered both unit and amorphous food items. The effect was not restricted by food type**, child age or** influenced by initial portion size served. **Of the studies included in the meta-analysis between study heterogeneity was low suggesting minimal variation in treatment effects between studies, however,** more research is required to understand the mechanisms of the PSE in preschool children. Future research should determine feasible methods to downsize portion sizes served to children.

Keywords: Portion size, Consumption, Systematic Review, Meta-analysis, Unit, Amorphous, Children

Background

Parents are often perceived as role models for their children's health related behaviours (1). They shape their children's food preferences, consumption and general diet quality due to modelling behaviours (2) and the type and quantity of food they make available within the household (3). However, when it comes to determining an acceptable portion size for children, most parents describe various strategies for determining portion size, however, few mothers said they use actual measurements or expert recommendations (4). Instead, contextual factors such as time of day, proximity to last eating occasion, adult portion sizes or package size are considered (4,5). Whilst appropriate portion sizes are typically given for adults on pre-packaged foods, this is not adjusted for children's age or stage of development, often leading to an overestimation in the amount children require. Since the 1970's, food portion sizes and the size of serving utensils and equipment used to prepare food have increased (6). This may promote overeating and change perceptions of portion size norms (7).

Children's eating patterns track into later life, therefore, early experience is critical for setting the foundations of healthy eating (8). As infants develop they move from appetite driven by internal cues to becoming more susceptible to external cues which can override self-regulation (9) and lead to eating in the absence of hunger (10). Exposure to large food portion sizes is one environmental cue that has been positively associated with an increase in energy intake. When individuals are presented with a larger than normal portion size they tend to consume larger amounts, thus their total energy intake increases (11–15). This is known as the portion size effect (PSE), which has been reported to affect consumption in adults and children from as young as two years old (16–18). A meta-analysis including 65

studies and 109 observations revealed that doubling the amount of food served to children and adults leads to an average increase in food intake of 35% (19). Increased portion sizes of high energy dense (HED) foods may play a role in contributing to the rising prevalence of overweight and obesity. For example, when manipulated over 2 (11), 4 (20) and 11 days (12) the PSE has been associated with a sustained increase in energy intake, without compensatory behaviours (21).

One explanation that has been offered to explain the PSE is that people consider a single unit to be an appropriate amount to eat. Consumption norms promote the tendency to consume one unit of food in its entirety, assuming that the unit is of some minimal size. This is known as unit bias, which has been found to influence the quantity consumers eat regardless of the unit size offered (22). Subtle visual cues pertaining to the portion size of foods are also thought to contribute to how much one consumes. For example, both adults and children perceive circles of a given size as being larger when surrounded by smaller sized circles in comparison to larger circles (23), such that the context in which an object is presented can affect judgement of its size (24). This is known as the Delboeuf illusion (25). Both children and adults demonstrate greater difficulty in judging the portion size of amorphous foods compared to unit foods. This may be because unit foods have a distinct shape whereas amorphous foods take the shape of its container (26). When children make judgements about food size it tends to be influenced by food diameter and height, rather than mass or volume (27), therefore when amorphous foods were doubled in size in a laboratory setting, children seemed largely unaware of this change (28).

Food shape is a potentially important dimension underlying the PSE as the amount of food available appears to impact portion size judgement which may in turn affect the amount of food children consume. In one study children served themselves on average 238.9kcal more of unit food compared with amorphous food, leading to a 102.73 kcal increase in

consumption (29). However, it is unclear if this was a result of food shape or children's preference for the unit food items. The aim of this systematic review and meta-analysis was to investigate the impact of offering unit or amorphous food on the PSE in children aged 2 to 12 years.

Methods

This systematic review and meta-analysis was registered with the International Prospective Register of Systematic Reviews (PROSPERO) (record # CRD42016035321) and conducted in two phases. Phase 1 included an extensive systematic review of literature, conducted to identify whether food type interacts with portion size to influence intake in young children aged 2-12 years. No restrictions were applied to the publication date. The search was limited to peer-review journal articles published in English (see Table 1). Phase 2 comprised a meta-analysis, including studies identified from the systematic review process that contained the required statistical information.

Search Strategy

Initially a scoping search was conducted in MEDLINE to map out the literature that exists on children's susceptibility to the PSE and to establish whether any current review had been undertaken on the topic. The scoping search was divided into a series of concepts (population, exposure, comparison), and alternative terms were formed. Search terms were adapted during the scoping search to include key words used in relevant studies and additional free-texts search terms were added to our initial MESH search terms. Using the revised search strategy, searches in MEDLINE, PsycInfo and Web of Science databases were conducted in February 2018. Search terms were combined as follows: (portion* NEAR/4

(food* or meal* or snack* or eat* or consum* or diet*)) AND (portion* NEAR/4 (size* or large* or small* or reference or big or medium)) AND (child* or infant* or schoolchild*). To identify papers not captured by our database searches, we performed additional citation follow up searches by scanning through the reference list of the included studies.

Selection of studies

Papers were included in this review based on their relevance to address the review question based on the priori outcome measure: an objective measurement of food consumption (grams or kcal) and exposure to various food portion sizes. The first author screened titles, abstracts and full papers to determine their relevance using the preferred reporting for systematic reviews and meta-analyses (PRISMA) guidelines (30). A second independent reviewer (RA) cross checked all the included and excluded papers, to ensure that no relevant papers were excluded. Any disagreements about the inclusion of papers were resolved via discussions between authors.

The studies included in the systematic review met all the inclusion criteria and none of the exclusion criteria (see Table 1). Where publications included several dependent measures, only the outcomes that met the inclusion criteria were included. Studies were included if the participants were under the age of 12 and had been exposed to varying portion sizes of food. Papers that did not meet the inclusion criteria were excluded.

152 Table 1: Inclusion and Exclusion Criteria for review of studies

	Inclusion	Exclusion
Population	Children aged 12 years and below. No restrictions on ethnicity, socioeconomic class or gender.	Children older than 12years
Intervention/ Exposure	Exposed to multiple portion sizes of food. Portion size served measured objectively (grams or kcal)	No exposure to portion size manipulation, portion size manipulation of a non-food item e.g. beverages or subjective/ unknown measure of portion size served
Outcome	Amount of food consumed to be measured objectively (grams or kcal)	Unknown quantity of food consumed, or amount measured subjectively
Study Type	Quantitative (quasi-experimental, observational) primary data, published in English in a peer review journal. Full length text. No restriction on publication date or sample size. Lab based and in natural environments	Qualitative evidence, systematic reviews, meta-analyses and abstracts from conferences

153

154 Data extraction and quality assessment

155 The first author extracted information related to the outcome measure (food intake) and
156 exposure (initial and manipulated portion size). This was crosschecked by a second
157 independent reviewer (RA) to reduce bias. The following information was extracted using a
158 standardised checklist: study design, recruitment method, study location and time,
159 participants (age, sex, ethnicity, socioeconomic status) type of food served, amount of food
160 served (grams or kcal), amount of food consumed (grams or kcal) at each portion size, and
161 study limitations. Some authors did not provide information regarding the amount (grams or
162 kcal) consumed in each portion size condition (31,32). In these cases the lead author was
163 contacted for the relevant information.

Assessment of study quality was undertaken for all studies using a checklist based on a combined measure previously used by Downs and Black (33) and the National Institute of Clinical Excellence (34), and adapted for use in the assessment of quality of studies (35). The scale was chosen based on its appropriateness to appraise a variety of study designs and it has been used previously to grade the quality of studies in a similar systematic review that explored parental styles, feedings styles and feeding practices (36). The quality assessment tool contained 11 items that were scored on a Likert scale using values of 0 = no, 1 = partly and 2 = yes to provide each paper with a total score out of 22 to reflect its quality (35). Papers were rated on their chosen study design, methodology, analysis and interpretations of findings and were sensitive to portion size research. For example, questions relating to baseline hunger, portion size and food liking were included. Two independent authors (SR, RA) scored all the papers, and a third reviewer scored 10% (SC). Minor disagreements were resolved through discussion.

Definition of exposure categories

Baseline portion size varied across studies, according to participant age and food type, and the majority of studies considered multiple experimental groups. Therefore, the PSE was assessed for multiple different magnitudes of portion size increase. Each experimental group was described using the percentage increase in portion size (note that individual studies may contain multiple experimental groups). These experimental groups were categorised according to six exposure groups to describe the percentage increase in portion size from baseline: 0-50%, 51-100%, 101-150%, 151-200%, 201-250%, 250-300%, with a further seventh category used to describe situations when the percentage increase in portion size was not clear.

188 Meta-analysis

189 Exposure groups whereby baseline portion size was increased by 51-100% were included in
190 the meta-analysis. Inclusion of only one portion size group per study was necessary in order
191 to avoid introducing correlation due to multiple comparisons (37); section 16.5.4].

192 To allow comparison across different measurement scales (kcal, g), standardised mean
193 differences (SMDs) were calculated (37).

194 Synthesis

195 The SMDs were synthesised using a random effects model, which allows for heterogeneity
196 between studies due to differences in individual study protocols. Heterogeneity was explored
197 by considering potential effect modifiers using meta-regression (37,38). Three potential effect
198 modifiers were considered in isolation as past research has suggested these may be influential
199 in the PSE (16,19,31): baseline portion size, mean child age and food type.

200 Analyses were conducted in the R (39) statistical software package, using the "metafor"
201 package (40). Some studies described more than one experimental group (including different
202 age groups and different food types). A multilevel model was therefore used, with random
203 effect (RE) at the study level. Results are presented in a forest plot, showing the overall
204 pooled result for the primary meta-analysis (without inclusion of moderators) (Figure 2), as
205 well as the pooled estimates according to food type served.

206 After synthesis, SMD's were re-expressed using familiar metrics (41) for ease of
207 interpretation. The average (mean) daily energy intake from a representative sample of
208 children aged 4-10 years old (42) was re-expressed in terms of proportionate (%) and
209 absolute change (kcal) following increases to food portion size. Further details on this method
210 are reported in a Cochrane review (43).

Assessment of reporting biases

Funnel plots were created to detect possible reporting biases in the meta-analysis (44). The results were interpreted via visual inspection. In the absence of bias the funnel will resemble a symmetrical inverted funnel, whereas asymmetry or skewness indicates bias.

Results

The search returned 1197 articles, and after duplicates were removed (n=294) 903 papers were screened (Figure 1). Hand searches of the reference list identified 21 potential qualified papers. However, after applying the inclusion criteria at the abstract level, only 2 papers qualified. Overall, 57 full text articles were screened. Thirty-six articles were excluded due to the age of the participants, the study design or where portion size had not been manipulated. In total, 21 articles, **reporting on 23 studies and 39 conditions/ exposure groups**, met the eligibility criteria and were included in the systematic review (16,18,50–59,28,60,31,32,45–49) of which 14 **articles** reporting on **14** studies **and 24 conditions/ exposure groups**, provided requisite statistical information for inclusion in a random effects model meta-analysis (16,18,52–55,28,45–51).

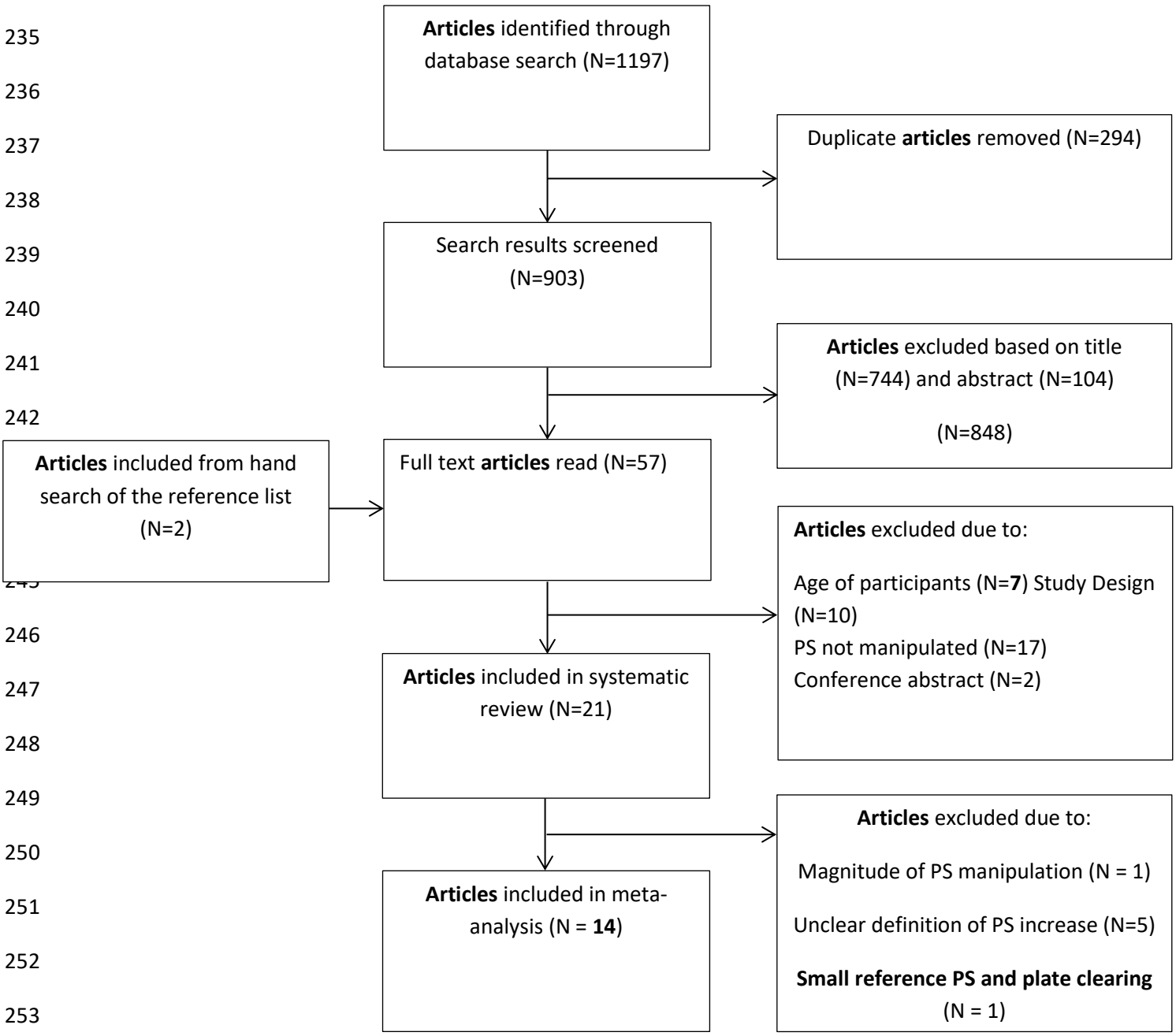

Figure 1: PRISMA flow diagram of search results, screening and included articles

Study characteristics

The characteristics of the studies included are presented in Table 2. Both male and female participants of cross cultural and varying socioeconomic backgrounds, between the ages of 2 and 12 years were included. The sample size ranged between 17 (32,53) and 225 (48). Most studies (n=17) were conducted in the USA (16,18,53–58,60,28,32,45,46,49–52). One study was conducted in the Netherlands (48), one in China (59), one in Belgium (47) and another in Singapore (31). Both laboratory (n=11) and natural environments (n=10), such as day care centres and nurseries were used.

Studies assessed food intake when the portion size of food was amorphous in presentation (n =13) (16,28,56,59,60,31,32,47,51–55), unit (n=7) (18,47,48,50,51,57,58) or both amorphous and unit (n=3) (45,46,57). Two studies (47,51) included both unit and amorphous items, however these were manipulated at separated eating occasions, therefore they feature as individual exposure groups in both the amorphous and the unit section. With the exception of three studies, serving soup (52) and a rice, vegetable and protein mix (31,59) all studies providing an amorphous meal used a pasta dish such as macaroni and cheese (16,28,32,51,54–56,60). Unit food items included chicken nuggets (58), hash browns (49), popcorn (47), fruit (18) and vegetables (48).

Most studies included an exposure group which enhanced food portion size by 51-100% relative to baseline (n=15) (16,18,51–55,28,32,45–50) (Table 3, Appendix 1). Four studies also looked at a 150% (45,46,49,55) and a 300% serving (50) (Table 4, Appendix 1). Three studies (52,56,59) examined smaller increases in portion size < 50% or manipulated portion size unique to the individual using self-serve methods (31,58,60), thus food intake was examined for a variety of portion sizes and serving methods.

Studies reported intake by weight (grams, n = 16) (18,28,55–60,31,32,46–48,50,52,54) or energy (kcal, n = 5) (16,45,49,51,53). The time at which food was served varied between studies (snack time (n=3), lunch (n=9), evening meal (n=7), or over a 24-hour period (n=2)). However, most studies (n=16) accounted for hunger levels by taking a subjective measure of hunger (n = 4) (47,48,55,59), provided a set meal before consumption (n = 5) (32,50,52,53,56), or requested that parents restricted their child's intake of food and drink 2-3 hours prior to the testing session (n = 6) (16,18,49,54,57,60).

Insert table 2 here

Quality assessment

The maximum score that could be achieved was 22. The scores ranged between 17 (58) and 21 (31) providing evidence of reasonable quality across studies. Studies tended to score highly for their rigorous research design and adequately drawn conclusions. However, studies tended to score lower on the question regarding ethical considerations as very few studies provided sufficient detail which may be due to word restrictions. No studies were excluded from the systematic review based on their quality score.

Portion Size Effects

Amorphous foods

Nine (16,28,32,47,51–55) of the included studies reported that increasing the reference portion of an amorphous food by 51-100% significantly affected intake ($p < .05$). Children aged 2-9 years consumed significantly more soup (52), macaroni cheese (16,28,32,54,55), cereal (51), chocolate pudding, applesauce (53) and popcorn (47) when the portion size was doubled. However, children aged 5 years did not consume significantly more macaroni and cheese in the double (M=239, SD = ±118kcal) compared with the reference (M=226, SD =

±125kcal) portion condition ($p > .05$) when served alongside fixed, but generous, portions of carrot, cookies and applesauce (51).

Four studies (16,31,55,59) examined differences in intake based on age. One study reported that differences in amount consumed were not related to the age or sex of the children (16). Contrastingly, Rolls et al. (55) found that doubling the portion size of macaroni and cheese did not significantly impact consumption in children aged 3-4 (M= 44.80, SE= ±12.30g vs. M= 54.60, SE = ±15.80g, $p > .05$), although it did significantly impact intake in children aged 4-6 (M = 76.70, SE= ±14.80g vs. M=122.70, SE= ±21.60g, $p < .002$). Similar findings were observed when the portion size of amorphous food was increased by < 50% (Smith, 2013) or tailored to the individual (31). Increasing the portion size of a rice, vegetable and protein mix by 30% had no impact on intake in children ≤ 4 years old, yet children ≥ 6 years old consumed 36% more ($p < .01$) (59). Child age was also found to interact with serving method to influence the amount served and thus consumed at a lunch meal. Total serving and intake of macaroni and cheese were highest in the 150% condition compared with teacher and child-serve days but comparisons were only significant for children ≥ 6 years ($p \leq 0.04$), and not the younger children (3-5 years; $p \geq 0.17$) (31).

Two studies manipulated the portion size of macaroni and cheese by enlarging the portion size by <50% (56) or using self-serve methods (60) did not compare effects by age. Leahy et al., (56) found that increasing pureed vegetable content in pasta by 20g significantly increased vegetable consumption in children aged 3-5, such that they consumed an additional half serving of vegetables. Similarly, when macaroni and cheese increased in 60g increments from 60 to 400g, children aged 3-5 were reported to consume significantly more with each portion size increase. This positive association between portion size and consumption was also observed when children were able to self-serve. On average children consumed an additional 0.56 kcal of macaroni and cheese for each additional gram served (60).

Unit Foods

When the portion size of unit foods were increased between 51 and 100%, six (18,47–51) of the included studies reported a significant effect on intake ($p < .05$), similar to those that doubled the portion size of amorphous items (16,47,52–55,60). Children increased consumption of carrots (47%) (50), cucumber (54%) (48) and cookies (28%) (47) when doubled in portion size and served on their own as a singular food type. Children also increased consumption of unit foods when a variety of items were served together, such as chicken nuggets, hash browns, green beans and brownie (49), or when unit foods were served alongside a fixed portion of an amorphous item (18) or fixed portions of unit items (51). For example, children consumed 72% more fruit ($p < .0001$) and 38% more vegetables ($p < .01$) when the portion size was doubled and served alongside a fixed portion of pasta (310g) that fell between the 75th and 90th percentile of intake for children aged 2-5 years (61). Furthermore, children aged 5 consumed 34% more chicken nuggets when served alongside a fixed, but generous, portion of corn and bread roll (51). However, when the same sample of children were served a double portion of crackers, intake was unaffected. Similarly, Aerts and Smit (47) reported that children aged 3-6 did not significantly increase consumption of baby carrots at morning snack time when the reference portion was increased by 63%.

When children were able to self-serve unit foods for lunch in kindergarten, children opted for an average of 3.49 chicken nuggets (58). On fixed portion days children were served 4 chicken nuggets. This significantly affected intake ($p < .009$) such that children consumed 10% more on fixed portion days when more units were served compared to self-selected days when children served themselves less units.

Unit and amorphous foods

When the portion size of unit and amorphous items were increased by 51-100% within the same meal or snack occasion, three (45,46,57) of the included studies reported a significant impact on intake ($p < .02$).

When unit and amorphous items were doubled within one meal (45,46,57) significant increases in consumption were recorded. However, not all food items contributed to the increase in total energy intake. For example, Kling et al., (46) showed that serving a double portion of macaroni and cheese, chicken, vegetables, applesauce and ketchup increased intake of macaroni and cheese (31%), applesauce (64%) and ketchup (49%) ($p < 0.02$). Intake of chicken and vegetables remained similar between portion size condition. Similar findings were observed when fruit and vegetable side dishes were doubled in portion size (57). Total intake increased ($p < .01$), due to a 43% increase in applesauce ($p < .01$); carrot ($p = .60$) and broccoli ($p = .74$) consumption did not differ between conditions. Furthermore, when the portion size of macaroni and cheese, corn, applesauce and cookies was doubled in a laboratory total energy intake increased ($p < 0.01$) (45). The overall effect on total energy intake was due to an increase in the HED macaroni and cheese (21% increase across conditions) and cookies (a 60% increase across conditions) rather than the other food items.

Meta-analysis

Studies included in the meta-analysis

A total of **14 papers, contributing 14 unique** studies **and 24 conditions/ exposure groups testing the effect of a 51-100% increase in portion size on food intake in children aged 2-12 years old** were included in the meta-analysis. Of the 21 papers **(contributing 23 studies and 39 conditions/ exposure groups)** initially considered for inclusion in the meta-analysis, one **study** was excluded as the portion size was not increased by 51-100% (56) and five **articles contributing 6 studies** did not use a clear definition of portion size increase (31,57–

60). Furthermore**, two studies were excluded since evidence of plate clearing was detected (Savage et al. 2012** (32) **and Aerts et al. 2017** (47) **(study A). Plate clearing was defined on the basis that the children consumed more than or equal to 90% of what was offered** (62)**. Note that although Aerts study A** (47) **was removed due to plate clearing, there was no evidence of plate clearing in Aerts study B** (47) **and so this study was retained for the analysis. Moreover in the Savage et al. paper** (32) **the reference portion size was unusually small.** More detail on this is provided in the discussion section **and in Appendix 1, Table 4.**

Results of the meta-analysis

Results of the primary meta-analysis and the meta-regression including food type as a moderator are shown in Figure 2. When children aged 2 – 12 years were offered unit, amorphous or both unit and amorphous food items the pooled SMD was **0.47 (95% CI: 0.39-0.55)** indicating a statistically significant PSE (Figure 2). The pooled SMD indicates that a portion size increase of 51-100% is associated with an SMD of **0.47**, which can be re-expressed as equivalent to a **13% (186kcal)** increase in average daily energy intake.

The test for residual heterogeneity was not significant (Q = 27, df = 23, p = 0.24) suggesting minimal variation in treatment effects between studies.

Three effect modifiers were explored including, initial portion size, mean age and food type (unit, amorphous and, unit and amorphous), testing each one in isolation in a meta-regression. Inclusion of the continuous covariate for initial portion size (in grams for all studies) was found to be **non- significant (coefficient = -0.0004, 95% CI: -0.0009 - -0.0001, p = 0.14)**. **Indicating the initial portion size does not impact upon the portion size effect.** Mean study group age was missing for one study (54), however the age range was given as 5-6 years, and so mean age was assumed to be 5.5 years. Inclusion of a continuous covariate for

mean age was not significant (coefficient = **0.02, 95% CI: -0.03 - 0.06, p = 0.47**)**, suggesting that the portion size effect is not associated with age.**

The impact of food type was assessed by including food type as a moderator with 3 levels (amorphous; unit; amorphous and unit). The PSE was found to be statistically significant in all subgroups, with the largest pooled SMD for unit (SMD = 0.53, 95% CI: 0.41 - 0.66), then unit and amorphous (SMD = 0.47, 95% CI: 0.32 - 0.62) and amorphous (SMD = 0.39, 95% CI: 0.25 - 0.43). (Figure 2). The overall test for food type as a moderator was not statistically significant (p= 0.33).

Visual analysis of the funnel plot demonstrated **relatively good symmetry suggesting the absence of reporting bias (Figure 3).**

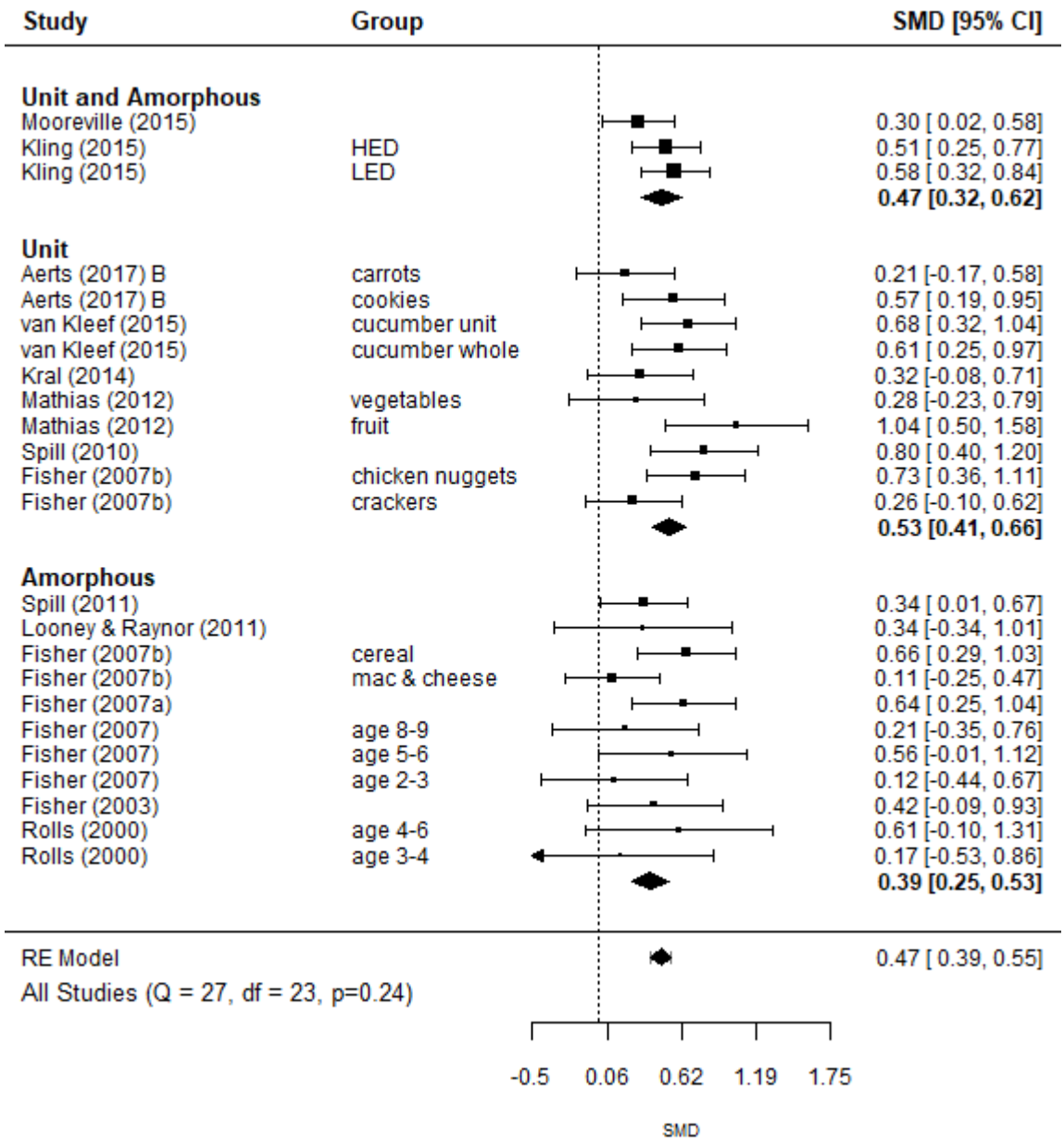

Figure 2: Forest plot of random effects meta-analysis for all exposure groups, and according to food type served

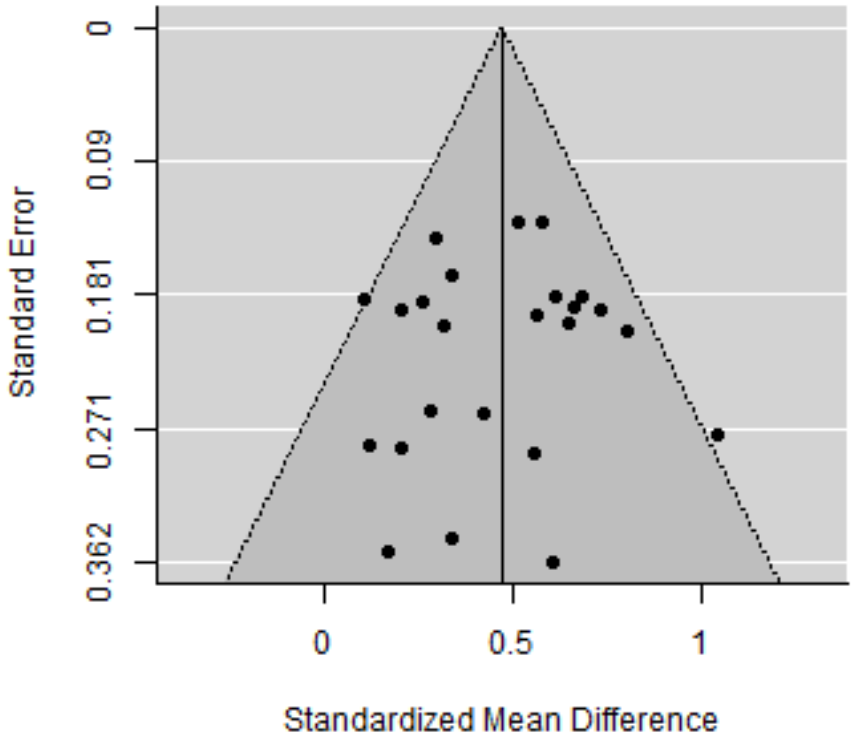

Figure 3: Funnel plot to detect possible reporting bias

Discussion

The purpose of this review was to investigate the impact of offering unit or amorphous food (i.e. food type) on the PSE in children aged 2 to 12 years old. The meta- regression did not reveal a significant difference in the magnitude of the PSE based on food type served, child age **or initial portion size served**. Overall, the PSE was observed across studies, at all eating occasions, including breakfast, lunch, dinner and snacks, and for all food types.

The analysis revealed no complex interplay between the PSE and the type of food served. However, several studies were removed from the meta-analysis. For example, in one study portion size did not increase by 51-100% (56) and several studies were unclear about the magnitude of the portion size increase (31,57–60). The reference and enlarged portion sizes served in the Savage et al., (32) study were much smaller, and thus not comparable to the other included studies. **T**he reference and enlarged portion size **used in this study** were smaller than the average quantity of macaroni and cheese consumed by children aged 2-5 years in the USA, as demonstrated in the Continuing Survey of Food Intakes by Individuals (61). The small portion sizes offered may explain why children appeared to consume all **(90% or more)** that was offered to them. Similarly, children in **one of the studies (study A) in the Aerts et al. paper** (47) **demonstrated plate clearing; the children consumed all of the popcorn that was offered to them in both the reference and large portion size conditions. As a result this study was also excluded from the meta-analysis. A decision to keep in the second study (study B) from the Aerts et al.** (47) **article was made due to the absence of plate clearing. The inclusion of Savage et al.** (32) **and Aerts et al.** (47) **studies may have produced an inflated, artificial SMD thus not producing a true effect.**

Increasing children's portion size by 51-100% produced a significant PSE. It is possible that children were unable to detect changes to the portion sizes on offer irrespective of food type

458 (28). Alternatively, children this age typically clean the plate or eat most of what is offered as
459 an expectation placed on them by parents. Given that children are known to eat all that is
460 served to them (5) and are encouraged to clear their plate (63) parents and caregivers may
461 promote overconsumption. Recent survey data suggests that parents are unaware of age
462 appropriate portion sizes for their children and often provide larger portions than deemed
463 suitable (64), which may inhibit self-regulation. Interestingly, when children self-served from
464 a regular and large serving dish, they served and thus consumed more from the larger serving
465 dish (60). These findings extend previous research suggesting that large food portion sizes
466 not only stimulate intake when served directly to children, but also when children are allowed
467 to serve themselves. These actions may be acquired through experience from parents or from
468 social norms set by decades of increasingly large food portion sizes on offer in the
469 marketplace (6).

470 **In a previous meta-analysis** Zlatevska et al. (19) identified the PSE to be curvilinear with a
471 possible ceiling effect, perhaps due to an increase in salience and reliance on internal cues.
472 Similar findings have been reported in a study examining the magnitude of the PSE when all
473 components of a meal with varying energy densities were increased in size (65). For example,
474 as food portion sizes got larger participants consumed an increasingly smaller proportion of
475 the amount served and the strongest predictor of food intake was the portion size offered.
476 **However, the results of the current meta-analysis do not fully support these findings.**
477 **The initial portion size did not significantly affect the PSE. This finding might be due to**
478 **the relatively small number of studies included in the meta-analysis. Moreover, the**
479 **initial portion size moderator analysis did not account for type of food used. This might**
480 **be of potential interest in future investigations since there might be a relationship**
481 **between portion size and energy density, whereby larger portion sizes may be less**
482 **energy dense than small ones.**

The largest increases in consumption were observed when unit foods increased by 51-100% in portion size. According to the 'unit bias' mechanism consumers associate a single serving as being an appropriate amount to eat, regardless of its size (e.g. one sandwich) (22)**. As such, people tend to eat one unit of food. Moreover, when multiple smaller units are on offer, as demonstrated in the included studies, consumers may justify the need to consume multiple units or additional items due to their smaller size** (66)**.**

It is possible that other unaccounted factors also contribute to the PSE. For example, when children were presented with multiple food items, not all items contributed to the PSE (46,57) and serving method was also shown to be influential. Children increased intake of some foods but not others when presented with a variety. These findings have been observed elsewhere in the literature (45), with children increasing intake of their preferred foods, which were high in energy density and palatability (e.g., cookies, when served in combination with less preferred foods of low energy density; LED). These findings suggests that in order for children to consume more LED foods such as fruit and vegetables, food preference and the competing foods on offer should be taken into account (46). For example, some studies have reported that portion size had no effect on vegetable consumption when vegetables were provided as part of a main meal (57). Yet when vegetables were served before the main meal, in the absence of competing foods, the PSE was observed for both unit (carrot) (50) and amorphous (vegetable based soup) (52) vegetables. Therefore, it is possible that children's familiarity and preference for the competing foods on offer influences the PSE. Thus, the PSE may encourage intake of healthy, core foods such as fruits and vegetables if served in isolation.

Children of all ages within the review demonstrated susceptibility to the PSE by consuming larger amounts when provided with larger food portion sizes. Previous research has shown

508 that infants and pre-school children have the ability to self-regulate energy intake in
509 controlled laboratory conditions (67,68) suggesting a developmental shift in children's
510 susceptibility to the PSE. However, the current review suggests that external cues (e.g.
511 portion size) may become more influential in determining how much to eat and thus may
512 promote energy intake in children from the age of 2 years old. Therefore, younger children
513 may not be protected against the effects of portion size, as previously thought (68).

514 Implications

515 This review demonstrates that children aged 2- 12 years are responsive to the PSE,
516 irrespective of food type or child age. This could have serious long-term implications for
517 children's health given that eating patterns track into later life (8). Ubiquitous exposure to
518 large portion sizes of HED foods has the potential to promote overconsumption especially
519 given that large food portion sizes are becoming increasingly accessible within the food
520 environment (6). Research has demonstrated that modest increases in fruit and vegetable
521 portion sizes can improve children's intake of these nutrient dense, LED foods (18) therefore
522 it is possible that downsizing methods could reduce intake of HED foods. Based on these
523 outcomes, a pilot investigation (ClinicalTrials.gov NCT03339986) (69) was designed to
524 explore the efficacy and acceptability of two portion control strategies on intake of HED
525 snacks in preschool children, with a focus on downsizing, since the amount of food served
526 appears to be a central determinant in the amount children consume e.g. (29).

527

528 Strengths, Limitations and future research

529 This review extends current evidence on the effect of large food portion sizes on children's
530 dietary intake (19,43) and makes a significant contribution to the literature by examining

three moderators in isolation, including the impact of food type. Furthermore, this review revealed that children as young as two years of age are susceptible to the PSE which highlights the developmental stage where intervention is warranted. **A funnel plot was created to detect reporting bias of the studies included in the meta-analysis. Visual inspection revealed good symmetry suggesting the absence of reporting bias.**

Limitations have been identified at different levels of the review; study selection, study design and analysis. While the review identified a large selection of studies that manipulated the portion size of food served to children, the search strategy was limited to the inclusion of peer-reviewed articles published in English. Therefore, it is possible that studies published in other languages or as part of a thesis, were excluded. Furthermore, many of the laboratory-based studies used a convenience sample of children attending the university nursery. This resulted in parents having an above average level of education and household income (28,32,52,56). Nevertheless, this review included studies conducted in natural environments where the sample was often diverse (49–52,54,56).

Some studies were excluded based on providing insufficient information regarding consumption. Most of the included studies observed the effects of enlarged portion sizes on children's intake at one meal or snack occasion which automatically biases the outcome towards children consuming more. The inclusion of smaller portion sizes would allow the effects of downsizing to be observed. Furthermore, if these studies were conducted over a longer time frame then possible dietary adjustments or compensatory behaviours could be examined.

The unit and amorphous subgroup was small, contributing little information with which to estimate the between study standard deviation thus resulting in wide confidence intervals.

555 Future research should aim to determine feasible methods parents can adopt to ensure their
556 children are receiving portion sizes in line with nutritional guidelines. Research suggests that
557 intake can be controlled via portion size, however to date these strategies have not been
558 translated into feasible interventions (70) nor have the effects of downsizing been observed.
559 Research should ideally be conducted within a natural environment such as at home or
560 preschool, to enhance ecological validity. Focusing on low-income parents would be
561 beneficial as this population is at greater risk of obesity (71) and are often underrepresented
562 in child feeding research (72).

563 Conclusion

564 This review suggests that children aged 2-12 years consume larger quantities of food when
565 provided with larger food portion sizes. It is likely that the PSE is not affected by food type,
566 although further work is required to consolidate this finding. The portion size served to
567 children appears to be a central determinant in the amount consumed. Therefore, the need for
568 portion control interventions is warranted. Future research should consider feasible and
569 acceptable methods to control the portion sizes caregivers offer to their young children by
570 observing the effects of downsizing strategies.

571

572 List of Abbreviations:

573 PSE = Portion size effect

574 HED= High energy dense

575 PROSPERO = International prospective register of systematic reviews

576 PRISMA = Preferred reporting items for systematic reviews and meta-analyses

577 SMD= Standard mean difference

SD = Standard Deviation

RE = Random effects

LED = Low energy dense

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Consent for publication: Not applicable

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Authors contributions:

SR identified the review question, conducted the searches and extracted the data. SR, SJC, RA quality appraised the included studies. JS ran the meta-analyses. SR, SJC, RA, JS, MMH and JC contributed to the writing of and approved the final manuscript.

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Table 2: Summary of included papers (The table is split into three sections by type of food that was manipulated; amorphous v unit v unit and amorphous)

Author and Date	Aims of Study	Participant and sample	Methods	Manipulated Food Items	Findings	Quality Rating
Amorphous Food Items						
Aerts and Smits 2017 (study **A**) (47)	To identify if children's snack intake is influenced by portion size and snack sweetness	28 children (16 boys and 12 girls) aged 6-7 years from four schools in Belgium.	A between subject design Morning snack time at school	Sugared and salted popcorn. Reference condition: 30g. Large condition: 60g.	Children ate significantly more popcorn from the large portion compared to the small portion. This relationship was observed for both sugared and salted popcorn; however the effect was more prominent in the sugared condition.	20
Fisher, 2007 (16)	The aim of the research was to systematically study the effects of age on children's responsiveness to large and self-selected portions	75 children (44 boys and 31 girls) in three age groups: 2-3, 5-6 and 8-9 years old. Non-Hispanic white	A between-subjects design (age group) with a within-subject component (PS) Evening meal in a laboratory	Macaroni and cheese with an energy density of 1.42 kcal/g. Reference condition: 200g (age 2-3) 250g (age 5-6) 450g (age 8-9). The amount provided in the reference condition was doubled for the large condition	Children consumed an average of 29% more in the large condition compared to the reference. The difference did not vary by age, order or preference for the food. Older children consumed more food than the younger children.	18
Fisher et al., 2003 (28)	To determine the effects of repeated exposure to a large portion of an entrée on preschool-aged children's awareness of portion size, self-	30 children (16 boys and 18 girls) aged 2.9-5.1 years attending a full-day day-care programme at The Pennsylvania	A within-subject crossover design Lunch meal in a laboratory	Macaroni and Cheese. Reference condition: 125g (< 4 years) and 175g (> 4 years). The amount provided in the reference condition was doubled for the large condition	Doubling the portion size of the entrée increased the children's entrée by 25 % and total energy intake by15 %. Increases in entrée intake were not significantly related to sex, age, or the order in which the 2 portion sizes were served	19

	selected portion size, and food intake	State University. Diverse ethnicity				
Fisher et al., 2007a (54)	To test the effects of portion size and ED on children's food and energy intakes at a meal	53 children (25 boys, 28 girls) aged 5-6 years old. Diverse ethnicity	A 2 (PS) × 2 (ED) within-subject factorial design Evening meal in a laboratory	Macaroni and Cheese with an energy density of 1.32 v 1.84 kcal/g. Reference condition: 250g. The amount provided in the reference condition was doubled for the large condition	Children consumed 33% more of the entrée in the large portion conditions than in the reference conditions. The entrée ED did not interact with portion size to influence gram intake of the entrée	19
Fisher et al., 2007b (51)	To observe the effect of large portions on daily energy intake in 5-y-old Hispanic and African American children from low-income families	58 children (24 boys, 35 girls) aged 5 attending a Head start programme in Houston. African American and Hispanic	A within-subject design Lunch meal in a laboratory	The amount served in the reference condition was: 453 kcal macaroni and cheese and 160 kcal oat ring cereal. The amount provided in the reference condition was doubled for the large condition	Doubling the portion size of macaroni and cheese did not impact intake, however doubling the portion size of cereal led to a 51% increase in intake	20
Fisher et al., 2013 (60)	This research experimentally tested effects of the amount of entree available and serving spoon size on children's self-served entree portions and intakes at dinner meals	60 children (27 boys, 33 girls) aged 4-6 years. Ethnically diverse.	A 2 (PS) × 2 (serving spoon size) within-subject design.	Macaroni and Cheese with an energy density of 1.55kcal/g. Reference condition: 275g. The amount provided in the reference condition was doubled for the large condition. Fixed portion of unsweetened applesauce (112g) baby carrots (39g), Chocolate chip cookies (33g) and	On average, children served 40% more entree when 550 g of the entree was available in the serving dish than when 275 g was available (91.9±14.7 vs 65.6±14.7 g; P<0.0001). Children consumed an additional 0.56 kcal of the entree and an additional 0.54 kcal total energy at the meal for every gram of macaroni and cheese served.	19

				2% milk (240g) was also provided.		
Leahy et al., 2008 (56)	To determine how incorporating extra vegetables in a meal impacts intake	61 (30 boys and 31 girls) aged 3.1-5.6 years attending full day day-care. Diverse ethnicity	A 2 (PS) × 2 (ED) within-subject factorial design Lunch meal in a laboratory	Pureed broccoli and cauliflower served with pasta and spaghetti sauce. Reference condition: 10.1g. Large condition: 30.1g	Vegetable intake significantly increased when the portion size was increased. Children ate half a serving more in the large versus reference portion size condition	19
Looney and Raynor 2011 (53)	To investigate the impact of portion size and energy density on intake, both grams and kilocalories, of snacks in preschool-aged children	17 (7 boys and 10 girls) aged 2-5 years attending full-day preschool at the Early Learning Center on the University of Tennessee Knoxville campus	A 2 (PS) × 2 (ED) within-subject factorial design Snack at preschool	Unsweetened apple sauce (0.43 kcal/g) and chocolate pudding (1.19kcal/g). Reference condition: 150g. Large condition: 300g.	A significant main effect of portion size occurred, with greater energy consumed in the large as compared to small portion, however, there was no main effect of energy density or interaction of energy density and portion size on energy intake	20
McCrickerd, Leong and Forde, 2017 (31)	To determine whether teacher-served portions impact children's food intake when increased in size	22 (11 boys and 11 girls) aged 3-6.8 years attending preschool	A within subject design Lunch meals at preschool	In the reference condition teachers served children a meal containing: mixed rice (white and brown) with protein (fish/ chicken/ egg/ tofu) and either steamed vegetables or vegetable broth. In the large condition, the	Children served and consumed similar amounts when they served themselves or were served by their teachers. However, when their teacher served them a 150% serving, they ate significantly more.	21

				amount served was calculated by multiply the amount consumed by each child by 1.5		
Rolls et al., 2000 (55)	To examine the effects of portion size on children's food intake	32 (14 boys and 18 girls) in two age groups: 3-4.1 (mean age =3.6) and 4.3-6.1 (mean age= 55) years attending a day care programme	A within subject design Lunch meal in a day care centre	Macaroni and cheese with an energy density of 1.4kcal/g Reference condition: 150g (age 3-4.1) and 225g (age 4.3-6.1). Medium condition: 263g (age 3-4.1) and 338g (age 4.3-6.1). Large condition: 376g (age 3-4.1) and 450g (age 4.3-6.1).	Older pre-schoolers consumed more macaroni and cheese when served the large portion than when served the smaller portion. In contrast, for younger children, portion size did not significantly affect food intake	18
Savage et al., 2012 (32)	To assess whether a linear increase in portion size influences preschool-aged children's intake of the entrée and of other foods served with the entrée, including fruit and vegetables	17 (7 boys and 10 girls) age 3-5 years attending pre-school	A within subject design Lunch meal in a pre-school	The amount served in the reference condition was 100g of macaroni and cheese. The portion size was increased by 60g in each condition, with the largest serving being 400g	Children consumed more energy from the entrée and more total energy as the portion size increased. Children consumed a decreasing amount of the other foods served with the entrée as the entrée portion size increased. Milk intake was unaffected by variations in the entrée portion size.	19

Smith et al., 2013 (59)	The aim of the research was to evaluate the association between age and the effects of portion size on food intake in Chinese children in a field-based setting	172 (93 boys and 78 girls) aged 4-6 separated into two age groups. Attending kindergarten in Kunming, Yunnan Province, China	A between-subjects design (age group) with a within-subject component (PS) Lunch meal in a pre-school	The amount served in the reference condition was 150 g (age 4) and 261g (age 6) of rice, vegetables and a protein mix. The small and large portion sizes were 30% lighter and 30% heavier than the reference portion size, respectively	Age was associated with a change in food intake. Only the 6-year-old age group ate significantly more with each increase in portion size. The 4 year old age group ate more in the reference and large portion compared to the small portion, however they did not eat more in the large compared to the reference	20
Spill et al., 2011 (52)	To determine the effects of serving different portion sizes of a low-energy-dense, vegetable-based soup on children's energy and vegetable intake within a meal and over the next eating occasion	72 (41 boys and 31 girls) with a mean age of 4.7 ± 0.1 attending one of two daycare centers on the University Park campus of The Pennsylvania State University	A within subject crossover design Lunch time in a day-care centre.	The amount served in the reference condition was 225g of tomato soup. The small and large portion sizes were 33% lighter and 33% heavier than the reference portion size, respectively	Intake of tomato soup was significantly affected by the portion size that was served. Doubling the portion size from 150 to 300g led to a significant increase in soup consumption by 23%, however the middle portion size was not significantly different than intake from either of the other portions	19
Unit Food Items						
Aerts and Smits 2017 (study **B**) (47)	To examine intake when children are served a small and large portion of a nutritious and less nutritious snack	55 children (19 boys, 26 girls) aged 3 to 6 years old from four classes in two schools in Belgium.	A 2 (portion size) X 2 (snack type) within subject design Morning snack at school	The first snack was baby carrots (35 kcal/100g) served in a regular 80g and large portion size 130g. The second snack was ladyfinger cookies (400kcal/100g) served	Children consumed significantly more cookies when offered the large versus regular portion. However, children did not consume significantly more carrots from the large compared to the regular portion.	20

				in a regular 30g and large portion size 48g.		
Fisher et al., 2007b (51)	To observe the effect of large portions on daily energy intake in 5-y-old Hispanic and African American children from low-income families	58 children (24 boys, 35 girls) aged 5 attending a Head start programme in Houston. African American and Hispanic	A within-subject design Lunch meal in a laboratory	The amount served in the reference condition was: 185 kcal graham crackers and 368 kcal chicken nuggets. The amount provided in the reference condition was doubled for the large condition	Doubling the portion size of crackers did not impact intake, however doubling the portion size of chicken nuggets led to a 34% increase in intake	20
Kral et al., 2014 (49)	To compare energy intake at a meal in normal-weight and obese children when the portion size of energy-dense foods and a sugar-sweetened beverage was systematically increased	50 (24 boys and 26 girls) aged 8-10 years old. Half of normal body weight and half classified as obese. Diverse ethnicity	A within-subject design with weight status as a between-subjects factor and portion size as a within-subjects factor Evening meal in a laboratory	The amount served in the reference condition was: 540kcal chicken nuggets, 378kcal hash browns, 94kcal ketchup, 31kcal green beans, 420kcal brownies and 100kcal fruit punch. 150 and 200% of this amount was served in the moderate and large portion conditions	Overall, children consumed significantly more in the moderate and large condition compared to the reference amount. Planned comparisons showed that obese children consumed significantly more calories during the meal compared to normal-weight children in all conditions	20
Mathias et al., 2012 (18)	To examine whether larger portions increase children's intake of both fruits and vegetables.	30 children (12 boys, 18 girls) aged 4 to 6 years old. Half were classified as overweight or obese.	A 2 (vegetable PS) x 2 (Fruit PS) within-subjects design.	Fixed portions of rotini pasta and tomato sauce (310g), 2% milk (244g) and a side of light ranch dressing (31g) were offered in all conditions. Only the portion sizes of the drained canned peaches in light syrup and cooked broccoli	Children consumed 41±6 g or 70% more fruit in the large portion conditions than in the reference conditions (59±5 g vs 101±9 g; $P<0.0001$), which corresponds to a two-fifths-of-a-serving increase. Children also consumed 12±4 g (37%) more of the vegetable side dish in the large portion conditions than in the reference conditions (32±6 g vs 44±9 g; $P<0.01$).	18

				were manipulated (75 v 150g)		
Ramsay et al., 2013 (58)	To compare kindergarteners' intake of food from a school lunch meal when they are pre-served a larger entrée portion to when they are allowed to choose from three preplated entrée portion sizes	114-121 kindergarten children attending a Kinder centre	A within subject design Lunch meal at preschool	The amount served in the reference condition was: 4 chicken nuggets. On self-serve days children had a choice of 2, 3 or 4 nuggets	On non-choice days 4 nuggets were served whereas not all Kindergarteners selected the largest nugget portion on choice lunches. This resulted in a significant decrease in chicken nugget intake between choice and nonchoice days	17
Spill et al., 2010 (50)	To determine the effects of serving preschool children different portions of a vegetable as a first course at lunch on vegetable consumption and energy intake at the meal	51 (22 boys and 29 girls) aged 3-6 (mean 4.4 ± 0.1y) enrolled in daycare at the Bennett Family Center at the University Park campus of The Pennsylvania State University	A within subject crossover design Lunch time in a day-care centre.	The amount served in the reference condition was 30 g of carrots. This was doubled and tripled for the moderate and large portion size conditions	Doubling the portion size led to a significant increase in carrot consumption by 47% whilst tripling the portion size led to a significant increase in carrot consumption by 54%	18
van Kleef et al., 2015 (48)	To investigate whether unit and portion size can be exploited to seduce children to eat more snack vegetables	255 (112 boys and 142 girls) aged 8 to 13 years. Attending primary school in the centre of the Netherlands	A 2 (PS) × 2 (unit size) within-subject design Morning snack at pre-school	The amount served in the reference condition was approximately one third of a cucumber (127g). The amount served in the large condition was approximately two-	Participants being presented with the large portion size ate about 54 % more cucumber relative to the small portion size	20

				thirds of a cucumber (248g)		
Unit and Amorphous Foods						
Kling et al., 2016 (46)	To examine the independent and combined effects on children's intake of changing the portion size and ED of all components of a meal	120 children (61 boys, 59 girls) aged 3-6 (mean 4.4 ± 0.1y) attending a childcare centre	A within subject crossover design Lunch meal in childcare centre	The experimental meal consisted of chicken (grilled breast or breaded nuggets), macaroni and cheese, a green vegetable (broccoli or peas), applesauce, ketchup, and milk. A 395g serving was provided in the reference condition. A 150 and 200% serving were provided in the medium and large condition.	There was a significant effect of portion size ($P < 0.0001$) but not ED ($P = 0.22$) on the weight of the meal consumed. Compared to the 100% portion size conditions, meal intake was 21% (60 ± 7 g) greater in the 150% portion size conditions and 26% (74 ± 7 g) greater in the 200% portion size conditions (both $P < 0.0001$).	19
Kral et al., 2010 (57)	To examine the effects of doubling the portion size of F&V side dishes on children's intake of F&V at a meal	43 (22 boys and 21 girls) aged 5-6 years old. Diverse ethnicity	A within-subject design Evening meal in a laboratory	The amount served in the reference condition was: 75g broccoli, 75g carrots and 122g applesauce. The amount provided in the reference condition was doubled for the large condition	Doubling the portion size of F&V side dishes resulted in a significant increase in the total weight of F&V consumed This resulted in a significant decrease in intake of the main entrée.	20

Mooreville et al., 2015 (45)	To evaluate associations of young children's susceptibility to large food portion sizes with child appetite regulation traits and weight status	100 (45 male and 55 female) aged 5-6 years. Non-Hispanic black. Normal weight (n=66) and obese (n=34)	A within-subject design with repeated measures Evening meal in a laboratory	The amount served in the reference condition was: 220g pasta, 84g corn, 127g applesauce and 25g cookies.150, 200% and 250% of this amount was served in the moderate, large and extra-large portion conditions	Total energy intake significantly increased from the reference portion to the 250% condition. The effect of portion size condition on total energy intake, however, did not vary by child weight status	19

Appendix 1

Table 3: Summary of evidence categorised by magnitude of portion size increase

Magnitude increase of portion size	Systematic review	
	Articles	**conditions/ exposure groups**
0-50%		4
51- 100 %	15	27
101-150%		3
151-200%		4
201-250%		1
250-300%		1
Not defined		

Table 4: Portion sizes served and quantities consumed for each exposure group (mean ± SD)

Study	Group	Food Type	Measure	Mean age	Participant count	PS1	Amount consumed PS1	PS2	Amount consumed PS2	Portion size group
Mooreville 2015[#]		Unit and Amorphous	kcal	5.4±0.5 (range: 5-6)	100	548	407.2±175.6	886	465.3±210.9	2
								1224	475.0±222.2	3
								1562	512.5±251.8	4
Kling 2016	HED	Unit and Amorphous	grams	4.4±0.1 (range: 3-5)	120	395	280±120.50	592	357±153.36	1
								790	360±153.36	2
	LED	Unit and Amorphous	grams	4.4±0.1 (range: 3-5)	120	395	283±109.54	592	331±142.41	1
								790	345±131.45	2
Kral 2010		Unit and Amorphous	grams	(range: 5-6)	43	272	-	544	-	2
Aerts 2017 (Study B)	LED	Unit	grams	4.67±0.86 (range: 3-6)	55	80	41.44±29.96	130	48.87±41.04	2
	HED	Unit	grams	4.67±0.86 (range: 3-6)	55	30	25.45±8.56	48	32.69±15.78	2
van Kleef 2015	One unit	Unit	grams	10.1±1.3 (range:8-12)	255	127	84.2±51.3	248	136.6±95.6	2

	Multiple units	Unit	grams	10.1±1.3 (range:8-12)	255	127	96.7±41.9	248	142.1±95.7	2
Kral 2014[#]		Unit	kcal	9.6±0.8 (range: 8-10)	50	1463	838±285	2195	947±292.1	1
								2926	928.5±285.0	2
Mathias 2012	Veg	Unit	grams	5.4±0.2 (Range:4-6)	30	75	32±32.86	150	44±49.30	2
	Fruit	Unit	grams	5.4±0.2 (Range:4-6)	30	75	59.0±27.39	150	101±49.30	2
Spill 2010		Unit	grams	4.4±0.2 (range: 3-5)	51	30	24.7±7.86	60	36.2±18.57	2
								90	38.1±22.85	4
Ramsay 2013		Unit	units	Kindergarten age	114-121	4 nuggets	-	Self- serve	-	7
Fisher 2007b	Crackers	Unit	kcal	5	58	185	94±66	370	115±92	2
	Chicken nuggets	Unit	kcal	5	58	368	267±96	736	357±143	2
Aerts 2017 (Study A)	Sugared	Amorphous	grams	6.43±0.68 (range: 6-7_	26	30	27.15±7.51	60	56.5±12.25	2
	Salted	Amorphous	grams	6.43±0.68 (range: 6-7)	28	30	23.89±10.08	60	42.63±11.95	2

Savage 2012		Amorphous	grams	4.3±0.5 (range: 3-6)	17	100	95.2±5.96	160	153.4±8.11	2
								220	171.9±45.63	3
								280	198.8±57.72	4
								340	234.3±76.47	5
								400	256.4±55.37	6
Smith 2013	Age 4	Amorphous	grams	4.1±0.4	94	150*	256±75	105*	179±73	1
								195*	183±76	1
	Age 6	Amorphous	grams	6.1±0.2	77	261*	325±118	182*	252±118	1
								339*	441±193	1
Spill 2011		Amorphous	grams	4.7±0.1 (range: 3-5)	72	150	108.4±51.76	225	122.1±76.37	2
								300	133±87.40	
Looney & Raynor 2011		Amorphous	kcal	3.8±0.6 (range: 3-4)	17	150	84.2±30.8	300	99±52.5	2
Fisher 2007b	Pasta	Amorphous	kcal	5	58	453	226±125	906	239±118	2

	Cereal	Amorphous	kcal	5	58	160	108±59	320	163±101	2
Fisher 2007a		Amorphous	grams	5.5 (range: 5-6)	53	250	158±80.08	500	210±80.08	2
Fisher 2007	Age 8-9	Amorphous	kcal	8.7±0.4 (range: 8-9)	25	450	361±173	900	407±258	2
								Self-serve	380±270	7
	Age 5-6	Amorphous	kcal	5.6±0.5 (range: 5-6)	25	250	223±83	500	290±145	2
								Self-serve	241±156	7
	Age 2-3	Amorphous	Kcal	2.6±0.5 (range: 2-3)	25	200	133±82	400	145±113	2
								Self-serve	127±92	7
Fisher 2003[#]		Amorphous	Grams/kJ	4±0.5 (range: 2-5)	30	150	1578±686.8	300	1922±910.4	2
Fisher 2013		Amorphous	grams	4.9±7.2 (range: 4- 6)	60	Self-serve	65.6±113.87	Self-serve	91.9±113.87	7
Leahy 2008	HED	Amorphous	grams	4.4±0.1 (range: 3-5)	61	10.1	5.3±1.56	30.1	15.6±6.25	1
McCrickerd 2017	Varied ED	Amorphous	grams	4.9 (range: 3-6)	22	self-serve	175.0±74.00	Teacher serve	175.23± 84.24	7

								Teacher-serve large	236.59±117.41	7
	Matched ED	Amorphous	grams	4.9 (range: 3-6)	22	Self-serve	245.77±120.93	Teacher-serve	234.50 ± 112.36	7
								Teacher-serve large	321.95 ± 164.88	7
Rolls 2000	Age 4-6	Amorphous	grams	5 (range: 4-6)	16	225	76.7±59.2	338	100.7±74.8	2
								450	122.7±86.4	2
	Age 3-4	Amorphous	grams	3.6 (range: 3-4)	16	150	44.8±49.2	263	54.6±63.2	2
								376	39.6±36.8	4

Key: portion size increase 1 = 0-50%, 2 = 51-100%, 3 = 101-150%, 4 = 151-200%, 5 = 201-250%, 6 = 251-300%, 7 =self-serve, * second servings allowed, # approximate SD