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

3

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35 Abstract

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

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

47 Increasing children's food portion size by 51-100% led to a significant increase in intake  
48 (SMD=0.47, 95% CI: 0.39 – 0.55). There was no evidence to suggest that increases in  
49 consumption were related to food type (p= 0.33), child age (p=0.47) or initial portion size  
50 served (p=0.14). Residual heterogeneity was not significant (p=0.24).

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

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

60 Background

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

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

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

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

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

107 consumption (29). However, it is unclear if this was a result of food shape or children's  
108 preference for the unit food items. The aim of this systematic review and meta-analysis was  
109 to investigate the impact of offering unit or amorphous food on the PSE in children aged 2 to  
110 12 years.

111

## 112 Methods

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

## 121 Search Strategy

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

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

#### 134 Selection of studies

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

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

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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.



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

177

178 Definition of exposure categories

179 Baseline portion size varied across studies, according to participant age and food type, and  
180 the majority of studies considered multiple experimental groups. Therefore, the PSE was  
181 assessed for multiple different magnitudes of portion size increase. Each experimental group  
182 was described using the percentage increase in portion size (note that individual studies may  
183 contain multiple experimental groups). These experimental groups were categorised  
184 according to six exposure groups to describe the percentage increase in portion size from  
185 baseline: 0-50%, 51-100%, 101-150%, 151-200%, 201-250%, 250-300%, with a further  
186 seventh category used to describe situations when the percentage increase in portion size was  
187 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).

211 Assessment of reporting biases

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

215 Results

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

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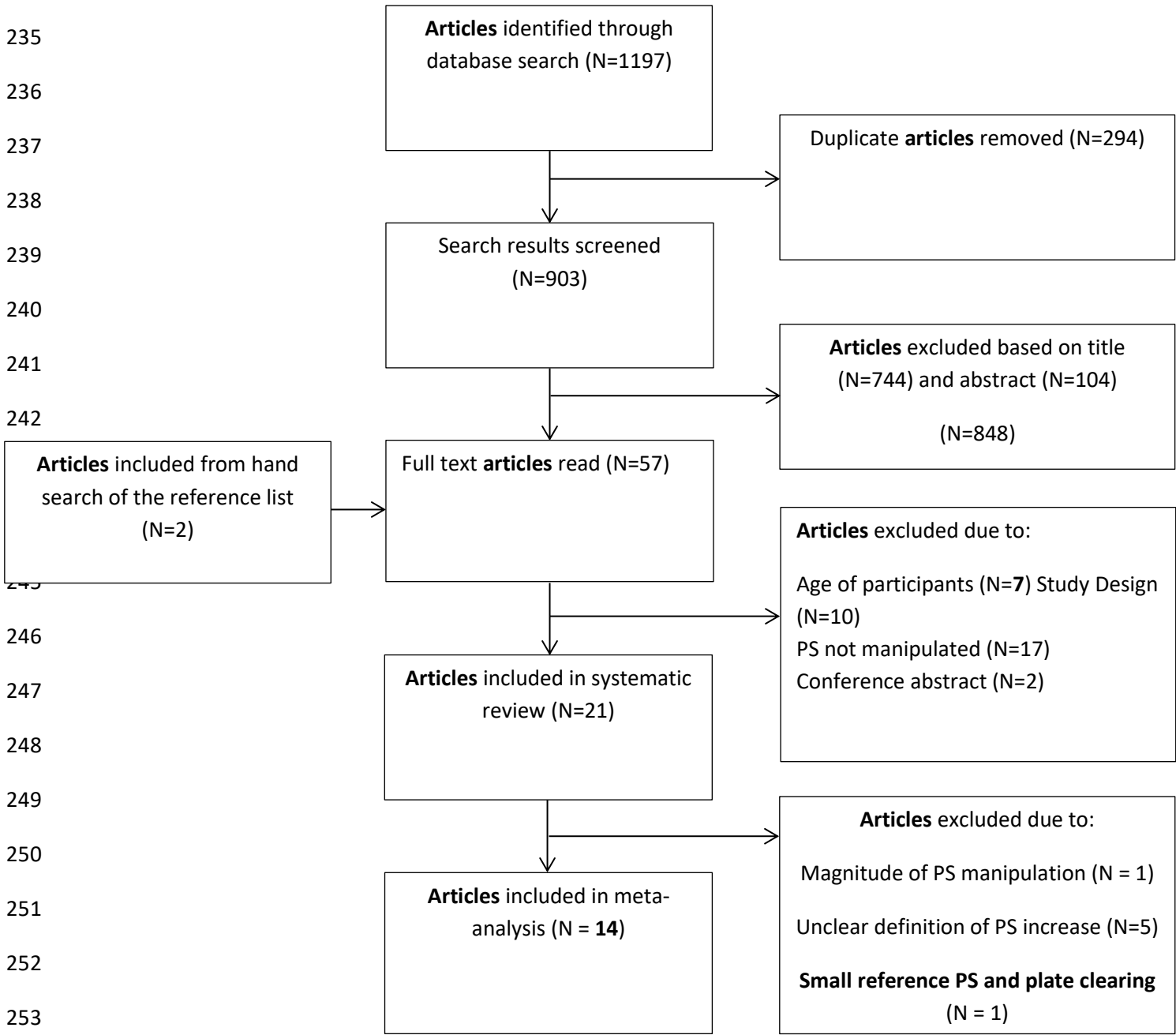
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258 Figure 1: PRISMA flow diagram of search results, screening and included articles

259 Study characteristics

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

267 Studies assessed food intake when the portion size of food was amorphous in presentation (n  
268 =13) (16,28,56,59,60,31,32,47,51–55), unit (n=7) (18,47,48,50,51,57,58) or both amorphous  
269 and unit (n=3) (45,46,57). Two studies (47,51) included both unit and amorphous items,  
270 however these were manipulated at separated eating occasions, therefore they feature as  
271 individual exposure groups in both the amorphous and the unit section. With the exception of  
272 three studies, serving soup (52) and a rice, vegetable and protein mix (31,59) all studies  
273 providing an amorphous meal used a pasta dish such as macaroni and cheese  
274 (16,28,32,51,54–56,60). Unit food items included chicken nuggets (58), hash browns (49),  
275 popcorn (47), fruit (18) and vegetables (48).

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

282 Studies reported intake by weight (grams, n = 16) (18,28,55–60,31,32,46–48,50,52,54) or  
283 energy (kcal, n = 5) (16,45,49,51,53). The time at which food was served varied between  
284 studies (snack time (n=3), lunch (n=9), evening meal (n=7), or over a 24-hour period (n=2)).  
285 However, most studies (n=16) accounted for hunger levels by taking a subjective measure of  
286 hunger (n = 4) (47,48,55,59), provided a set meal before consumption (n = 5)  
287 (32,50,52,53,56), or requested that parents restricted their child’s intake of food and drink 2-3  
288 hours prior to the testing session (n = 6) (16,18,49,54,57,60).

289 \*\*Insert table 2 here\*\*

## 290 Quality assessment

291 The maximum score that could be achieved was 22. The scores ranged between 17 (58) and  
292 21 (31) providing evidence of reasonable quality across studies. Studies tended to score  
293 highly for their rigorous research design and adequately drawn conclusions. However, studies  
294 tended to score lower on the question regarding ethical considerations as very few studies  
295 provided sufficient detail which may be due to word restrictions. No studies were excluded  
296 from the systematic review based on their quality score.

## 297 Portion Size Effects

### 298 Amorphous foods

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

305 ±125kcal) portion condition ( $p > .05$ ) when served alongside fixed, but generous, portions of  
306 carrot, cookies and applesauce (51).

307 Four studies (16,31,55,59) examined differences in intake based on age. One study reported  
308 that differences in amount consumed were not related to the age or sex of the children (16).  
309 Contrastingly, Rolls et al. (55) found that doubling the portion size of macaroni and cheese  
310 did not significantly impact consumption in children aged 3-4 ( $M= 44.80$ ,  $SE= \pm 12.30g$  vs.  
311  $M= 54.60$ ,  $SE = \pm 15.80g$ ,  $p > .05$ ), although it did significantly impact intake in children aged  
312 4-6 ( $M = 76.70$ ,  $SE= \pm 14.80g$  vs.  $M=122.70$ ,  $SE= \pm 21.60g$ ,  $p < .002$ ). Similar findings were  
313 observed when the portion size of amorphous food was increased by  $< 50\%$  (Smith, 2013) or  
314 tailored to the individual (31). Increasing the portion size of a rice, vegetable and protein mix  
315 by 30% had no impact on intake in children  $\leq 4$  years old, yet children  $\geq 6$  years old  
316 consumed 36% more ( $p < .01$ ) (59). Child age was also found to interact with serving method  
317 to influence the amount served and thus consumed at a lunch meal. Total serving and intake  
318 of macaroni and cheese were highest in the 150% condition compared with teacher and child-  
319 serve days but comparisons were only significant for children  $\geq 6$  years ( $p \leq 0.04$ ), and not  
320 the younger children (3-5 years;  $p \geq 0.17$ ) (31).

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

## 330 Unit Foods

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

347 When children were able to self-serve unit foods for lunch in kindergarten, children opted for  
348 an average of 3.49 chicken nuggets (58). On fixed portion days children were served 4  
349 chicken nuggets. This significantly affected intake ( $p < .009$ ) such that children consumed  
350 10% more on fixed portion days when more units were served compared to self-selected days  
351 when children served themselves less units.

352

## 353 Unit and amorphous foods



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

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

370 Meta-analysis

371 Studies included in the meta-analysis

372 A total of **14 papers, contributing 14 unique studies and 24 conditions/ exposure groups**  
373 **testing the effect of a 51-100% increase in portion size on food intake in children aged 2-**  
374 **12 years old** were included in the meta-analysis. Of the 21 papers (**contributing 23 studies**  
375 **and 39 conditions/ exposure groups**) initially considered for inclusion in the meta-analysis,  
376 one **study** was excluded as the portion size was not increased by 51-100% (56) and five  
377 **articles contributing 6 studies** did not use a clear definition of portion size increase (31,57–

378 60). Furthermore, **two studies were excluded since evidence of plate clearing was detected**  
379 **(Savage et al. 2012 (32) and Aerts et al. 2017 (47) (study A). Plate clearing was defined**  
380 **on the basis that the children consumed more than or equal to 90% of what was offered**  
381 **(62). Note that although Aerts study A (47) was removed due to plate clearing, there was**  
382 **no evidence of plate clearing in Aerts study B (47) and so this study was retained for the**  
383 **analysis. Moreover in the Savage et al. paper (32) the reference portion size was**  
384 **unusually small.** More detail on this is provided in the discussion section **and in Appendix**  
385 **1, Table 4.**

386 Results of the meta-analysis

387 Results of the primary meta-analysis and the meta-regression including food type as a  
388 moderator are shown in Figure 2. When children aged 2 – 12 years were offered unit,  
389 amorphous or both unit and amorphous food items the pooled SMD was **0.47 (95% CI: 0.39-**  
390 **0.55)** indicating a statistically significant PSE (Figure 2). The pooled SMD indicates that a  
391 portion size increase of 51-100% is associated with an SMD of **0.47**, which can be re-  
392 expressed as equivalent to a **13% (186kcal)** increase in average daily energy intake.

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

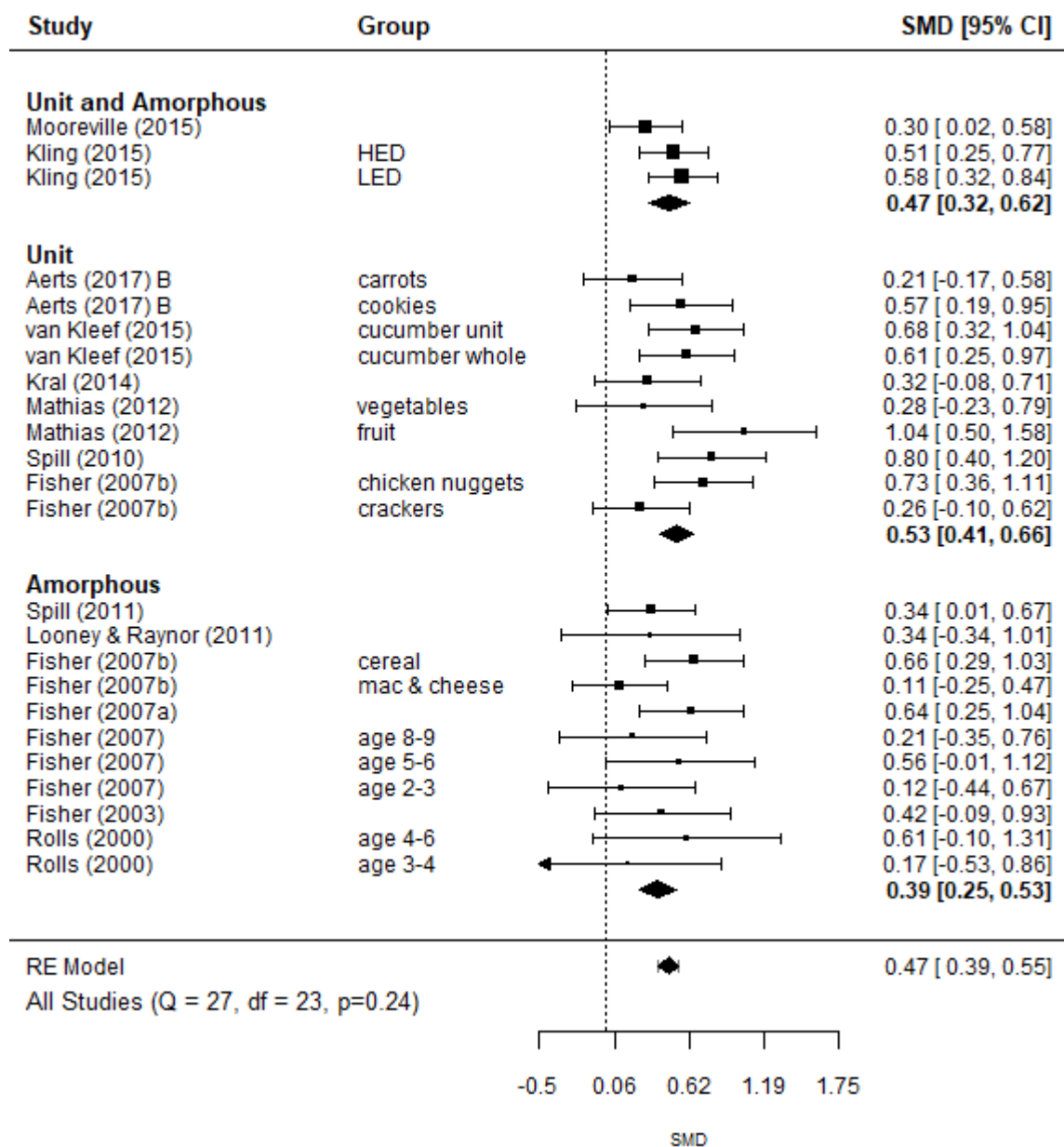
395 **Three effect modifiers were explored including, initial portion size, mean age and food**  
396 **type (unit, amorphous and, unit and amorphous),** testing each one in isolation in a meta-  
397 regression. Inclusion of the continuous covariate for initial portion size (in grams for all  
398 studies) was found to be **non- significant (coefficient = -0.0004, 95% CI: -0.0009 - -0.0001,**  
399 **p = 0.14).** **Indicating the initial portion size does not impact upon the portion size effect.**  
400 Mean study group age was missing for one study (54), however the age range was given as 5-  
401 6 years, and so mean age was assumed to be 5.5 years. Inclusion of a continuous covariate for

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

404 **The impact of food type was assessed by including food type as a moderator with 3**  
405 **levels (amorphous; unit; amorphous and unit). The PSE was found to be statistically**  
406 **significant in all subgroups, with the largest pooled SMD for unit (SMD = 0.53, 95% CI:**  
407 **0.41 - 0.66), then unit and amorphous (SMD = 0.47, 95% CI: 0.32 - 0.62) and**  
408 **amorphous (SMD = 0.39, 95% CI: 0.25 - 0.43). (Figure 2). The overall test for food type**  
409 **as a moderator was not statistically significant (p= 0.33).**

410

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



413

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

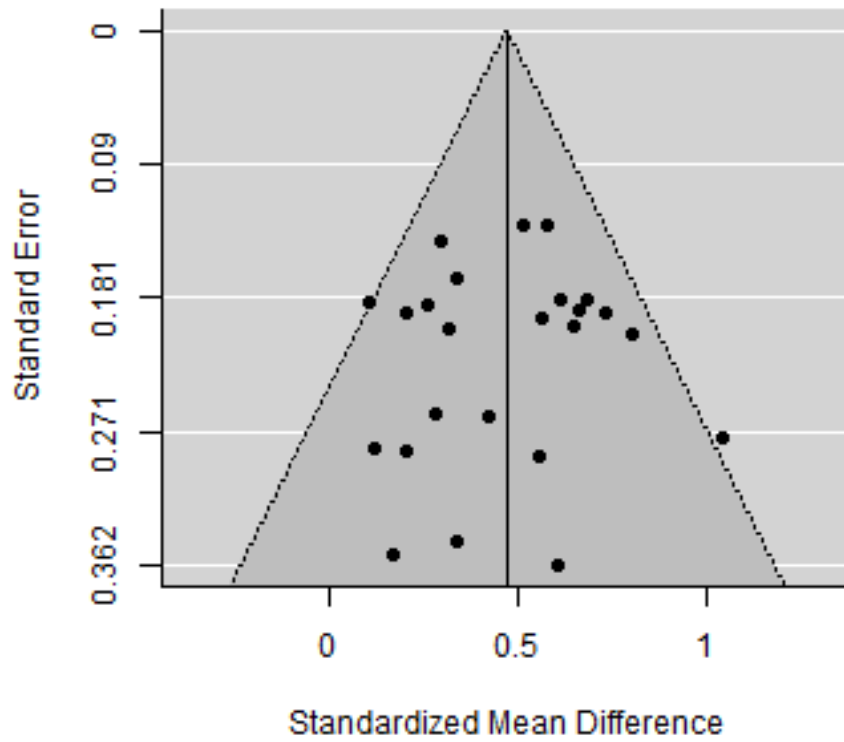
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Figure 3: Funnel plot to detect possible reporting bias

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434 Discussion

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

440 The analysis revealed no complex interplay between the PSE and the type of food served.  
441 However, several studies were removed from the meta-analysis. For example, in one study  
442 portion size did not increase by 51-100% (56) and several studies were unclear about the  
443 magnitude of the portion size increase (31,57–60). The reference and enlarged portion sizes  
444 served in the Savage et al., (32) study were much smaller, and thus not comparable to the  
445 other included studies. **The reference and enlarged portion size used in this study** were  
446 smaller than the average quantity of macaroni and cheese consumed by children aged 2-5  
447 years in the USA, as demonstrated in the Continuing Survey of Food Intakes by Individuals  
448 (61). The small portion sizes offered may explain why children appeared to consume all  
449 **(90% or more)** that was offered to them. Similarly, children in **one of the studies (study A)**  
450 **in the Aerts et al. paper (47) demonstrated plate clearing; the children consumed all of**  
451 **the popcorn that was offered to them in both the reference and large portion size**  
452 **conditions. As a result this study was also excluded from the meta-analysis. A decision**  
453 **to keep in the second study (study B) from the Aerts et al. (47) article was made due to**  
454 **the absence of plate clearing. The inclusion of Savage et al. (32) and Aerts et al. (47)**  
455 **studies may have produced an inflated, artificial SMD thus not producing a true effect.**

456 Increasing children's portion size by 51-100% produced a significant PSE. It is possible that  
457 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.**

483 **The largest increases in consumption were observed when unit foods increased by 51-**  
484 **100% in portion size. According to the ‘unit bias’ mechanism consumers associate a**  
485 **single serving as being an appropriate amount to eat, regardless of its size (e.g. one**  
486 **sandwich) (22). As such, people tend to eat one unit of food. Moreover, when multiple**  
487 **smaller units are on offer, as demonstrated in the included studies, consumers may**  
488 **justify the need to consume multiple units or additional items due to their smaller size**  
489 **(66).**

490 **It is possible that other unaccounted factors also contribute to the PSE.** For example,  
491 when children were presented with multiple food items, not all items contributed to the PSE  
492 (46,57) and serving method was also shown to be influential. Children increased intake of  
493 some foods but not others when presented with a variety. These findings have been observed  
494 elsewhere in the literature (45), with children increasing intake of their preferred foods,  
495 which were high in energy density and palatability (e.g., cookies, when served in  
496 combination with less preferred foods of low energy density; LED). These findings suggests  
497 that in order for children to consume more LED foods such as fruit and vegetables, food  
498 preference and the competing foods on offer should be taken into account (46). For example,  
499 some studies have reported that portion size had no effect on vegetable consumption when  
500 vegetables were provided as part of a main meal (57). Yet when vegetables were served  
501 before the main meal, in the absence of competing foods, the PSE was observed for both unit  
502 (carrot) (50) and amorphous (vegetable based soup) (52) vegetables. Therefore, it is possible  
503 that children’s familiarity and preference for the competing foods on offer influences the  
504 PSE. Thus, the PSE may encourage intake of healthy, core foods such as fruits and vegetables  
505 if served in isolation.

506 Children of all ages within the review demonstrated susceptibility to the PSE by consuming  
507 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

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

536

537 Limitations have been identified at different levels of the review; study selection, study  
538 design and analysis. While the review identified a large selection of studies that manipulated  
539 the portion size of food served to children, the search strategy was limited to the inclusion of  
540 peer-reviewed articles published in English. Therefore, it is possible that studies published in  
541 other languages or as part of a thesis, were excluded. Furthermore, many of the laboratory-  
542 based studies used a convenience sample of children attending the university nursery. This  
543 resulted in parents having an above average level of education and household income  
544 (28,32,52,56). Nevertheless, this review included studies conducted in natural environments  
545 where the sample was often diverse (49–52,54,56).

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

553 The unit and amorphous subgroup was small, contributing little information with which to  
554 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

578 SD = Standard Deviation

579 RE = Random effects

580 LED = Low energy dense

581

582 Declarations:

583 Ethics approval and consent to participate: Not applicable

584 Consent for publication: Not applicable

585 Availability of data and materials: All data analysed during this review are included in this  
586 published article

587 Competing interests: The authors declare that they have no competing interests

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590 Authors contributions:

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

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597

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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
<b>Amorphous Food Items</b>						
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 by 15 %. 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= 5.5) 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
<b>Unit Food Items</b>						
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

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	in a regular 30g and large portion size 48g. 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
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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  $\pm$  SD)

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

