When do children learn how to select a portion size?

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Competing interests

The authors declare that there are no competing interests.

Abstract

The reduction of portion sizes supports weight-loss. This study looks at whether children have a conceptual understanding of portion size, by studying their ability to manually serve a portion size that corresponds to what they eat. In a clinical setting, discussion around portion size is subjective thus a computerised portion size tool is also trialled, with the portion sizes chosen on the screen being compared to amounts served manually. Children (n=76) age 5-6, 7-8 and 10-11 were asked to rate their hunger (VAS scale), liking (VAS scale) and 'ideal portion size for lunch' of eight interactive meal images using a computerised portion size tool. Children then manually self-served and consumed a portion of pasta. Plates were weighed to allow for the calculation of calories served and eaten. A positive correlation was found between manually served food portions and the amount eaten ($r = .53$, 95%CI [.34, .82, $P<.001$), indicating that many children were able to anticipate their likely food intake prior to meal onset. A regression model demonstrates that age contributes to 9.4% of the variance in portion size accuracy ($t(68)= -2.3$, $p=.02$). There was no relationship between portion size and either hunger or liking. The portion sizes chosen on the computer at lunchtime correlated to the amount manually served overall ($r=.34$, 95%CI [.07, .55], $p<.01$), but not in 5-6-year-old children. Manual portion-size selection can be observed in five-year olds and from age seven, children's 'virtual' responses correlate with their manual portion selections. The application of the computerised portion-size tool requires further development but offers considerable potential.

1.1 Introduction

Consuming large portions of food is thought to play a causal role in promoting obesity (Hetherington & Blundell-Birtill, 2018; Ledikwe et al., 2005). At a population level, portion sizes have increased alongside obesity rates (Piernas & Popkin, 2011; van der Bend et al., 2017). Evidence suggests that children may be eating large portions and that in some cases they are offered adult-sized meals (Curtis et al., 2017). In addition, longitudinal studies indicate that meal size is an important driver of weight gain in early childhood (Syrad et al., 2016).

Decreasing portion size is a recommended intervention for weight-management (Barlow, 2007; WHO, 2015). However, exactly how much children should be eating, and how best to achieve this, is unclear (Eck et al., 2018). Currently, the United Kingdom National Health Service guidelines state “There is very little official guidance on precisely how much food children require, so you will need to use your own judgement” (NHS, 2020), leaving children’s portion sizes open to errors (Curtis et al., 2017; Eck et al., 2018). We also see evidence that parents who eat larger portions are more likely to feed their children large portions, which is likely to contribute to the intergenerational transmission of obesity within families (Potter et al., 2018).

In adults, large serving sizes promote the consumption of larger meals (Zlatohlavek et al., 2015) and in part, this may reflect a general tendency to engage in plate cleaning (Hetherington & Blundell-Birtill, 2018; Hinton et al., 2013). Remarkably, the same ‘portion size effect’ is also observed in children (Fisher & Kral, 2008) and some have argued that this sensitivity to portion size is promoted when parents encourage their children to clear their plate (Birch et al., 1987; Ramsay et al., 2010). In response, one suggestion is that children should be encouraged to self-serve in a ‘family style’ (i.e., from a central dish) (American Academy of Paediatrics, 2005). Self-serving is thought to facilitate the child’s innate self-regulation in response to internal signals associated with hunger and satiety.

In addition to encouraging personal portion-size decisions, children might also be trained to select healthier sized portions. One approach might be to monitor selections over a long period and to promote a gradual reduction in size and improved food choices (American Academy of Paediatrics, 2005). However, to realise this benefit it would be helpful to know whether and at what age children acquire a conceptual understanding of portion size. In adults, most meals are preselected and then consumed in their entirety (Fay et al., 2011), suggesting that pre-meal planning indeed plays an important role in energy intake. In children, a similar correspondence between meal planning and meal consumption would suggest they show the same conceptual understanding. In addition, other indicators might be explored to show evidence for pre-meal planning. For example, we might expect children to select smaller portions of foods that are less preferred or unfamiliar, and to select larger portions when they are hungry. Accordingly, in this study we assessed measures of portion selection, food intake, hunger, and food liking, with the first objective being to explore evidence for the same relationships that are normally observed in adults. Further, to explore a potential developmental trajectory, we actively recruited a range of children in order to achieve representation in three different age groups.

There are important potential therapeutic benefits of assessing meal planning. Specifically, it would be helpful to know how obesity interventions impact meal planning in children and whether new interventions might be developed to foster healthier dietary behaviours in this population. In many settings, the preparation and manual serving of actual food is impractical. Hence, portion selections have been assessed (in adults) using a validated computerised portion-size tool (Wilkinson et al., 2012), with respondents reporting their 'ideal' or 'typical' portion sizes by manipulating the amount of food shown on a computer monitor.

In paediatric weight management sessions, clinicians rely on verbal descriptions to assess food portions; a task that both children and adults find difficult (de Vlieger et al., 2019; Frobisher & Maxwell, 2003). A computerised portion size tool would deliver precise descriptions, but it remains unclear whether children can select portion sizes in this way. Therefore, our second objective was to evaluate this capacity. Using a computerised tool requires an ability to perceive portion size, together with an ability to predict an amount that will be needed to achieve satiation by the end of a meal (de Vlieger et al., 2019; M. Nelson et al., 1994; Subar et al., 2010). Though these skills are clearly evident in adults (Brunstrom, 2011; Brunstrom & Rogers, 2009; Fay et al., 2011; Hinton et al., 2013; Wilkinson et al., 2012), rather less is known about children, partly because studies have tended to focus on their ability to recall past meals (de Vlieger et al., 2019; Foster et al., 2008). One study indicates that children are comparable to adults (Sobo et al., 2000). However, others suggest that children have a limited capacity to form a conceptual representation of portion size and to plan meals on this basis (Baranowski & Domel, 1994; Livingstone & Robson, 2000).

In the present study we addressed two objectives. First, we sought to determine whether children have a conceptual understanding of portion size. Evidence was obtained by quantifying the following outcomes: a) the correspondence between physical self-selected portions and subsequent food intake, b) the correspondence between age and meal size and meal accuracy across three age ranges (5-6 years, 7-8 years, and 10-11 years) c) the relationship between portion size selection and hunger, d) the association between portion size and the extent to which a food is liked, and e) the associated tendency to plate clean after self-selection of real food . In all cases, we anticipated that these associations would be stronger in older children.

Second, to determine whether children have a capacity to use a computerised portion selection tool, we correlated the amounts of food selected using the computer programme with the amounts that children manually selected and then consumed.

2.1 Materials and Method

A protocol containing all methods and materials was uploaded to the Open Science Framework for transparency, prior to the start of data collection (https://osf.io/h7zmt/?view_only=d911f40d03d64b42a437fef5a59e3ee5).

2.1.1 Participants

Participants were drawn from three different school years, incorporating three distinct age groups (5-6 years, 7-8 years and 10-11 years) and were recruited at a single school in South-West England, UK, during a week-long science-engagement event. Exclusion criteria were an allergy or intolerance to foods within the task (i.e. vegetarian/vegan/gluten/dairy). The majority of participants were of normal weight, as determine by BMISDS (Pan & Cole, 2002). Participant summary statistics are displayed in Table 1. Children were invited to participate via a letter and participant information sheets were sent to the home of all families. Parents of willing participants returned the written consent to the school, together with the child’s choice of meal. Assent was requested from each child prior to testing.

Table 1. Participant characteristics (%)

	Total	Age 5/6	Age 7/8	Age 10/11
Number of participants	76	23	22	31
Male (%)	43 (57)	17 (74)	12 (55)	14 (45)
BMI-SDS (Pan & Cole, 2002) (%)				
Underweight	1 (1)	0 (0)	0 (0)	1 (3)
Normal	66 (87)	21 (91)	21 (96)	24 (77)
Overweight	6 (8)	2 (9)	1 (4)	3 (10)
Obese	3 (4)	0 (0)	0 (0)	3 (10)

2.1.2 Ethical approval

Ethics approval was given for this study by the University of Bristol, School of Psychological Science ethics committee REF 63241.

2.2 Materials

2.2.1 Meals and computerised portion-selection task

The research used a computerised portion task that incorporated images of eight lunches that differed in energy density (ED); penne pasta with tomato sauce (ED= 1.42kcals/g), lasagne (ED= 1.45 kcals/g), chicken curry (ED= 1.68 kcals/g), pizza and chips (ED= 2.77 kcals/g), macaroni cheese (ED= 1.51 kcals/g), breaded chicken with chips and beans (ED= 2.26 kcals/g), sausages with mash potato and peas (ED=1.63 kcals/g), and spaghetti Bolognese (ED= 1.41 kcals/g). A paediatric dietician, confirmed that these meals are likely to be familiar to children in the UK.

Meals were displayed on a computer screen and were presented on the same 255-mm diameter white plate. For each meal, a set of 51 images was taken using a high-resolution digital camera. The portion sizes of the meals increased in 25 kcal increments from 25kcal to 1250kcals. Children's portions are discussed throughout in kcals. The lighting and lens angle remained fixed in all images.

For each meal, participants were asked ''What is your perfect amount for lunch?'' Participants were instructed to move between portion sizes, to select a portion size using the arrow keys on the keyboard, and to press the 'Enter' key when they had selected an appropriate portion. Depressing the arrow keys caused the portion size to change with enough speed to give the impression that the plated portion was growing or shrinking. Each trial started with a different and randomly generated portion size. The protocol is based on methods reported previously by the authors (Wilkinson et al., 2012).

2.2.2 Hunger, Familiarity and Liking

A paper-based visual-analogue scale (VAS) with a 100-mm line with endpoints “Not hungry” to “Very Hungry” was accompanied by images of a bear with a different quantity of food in its stomach to represent varying hunger levels (Bennett & Blissett, 2014). Children were asked to “Please put a cross on the line according to how hungry you feel right now”. The anchor points were read out to ensure the child’s comprehension of the scale

Children were shown a picture of each meal and asked for a “yes” or “no” response to the question “Have you ever eaten food like this before?” Meals that were unfamiliar to the child were not included in the analysis.

Children were asked to rate their expected liking of each meal using a paper-based VAS scale comprising a 100mm line with end points “Very much” to “Not at all”. Five cartoon images of faces in traffic light colours representing different levels of liking from a green smiley face to a red sad face were included above the scale. Children were asked to indicate their liking of the food along the scale according to the question “How much do you like this food?”

A measure of post-meal liking was taken after children had eaten lunch, by asking the question “How much did you like your meal?” using a separate version of the above-mentioned VAS with traffic light cartoon faces.

2.2.3 BMI

Measures of height were obtained using a stadiometer (+/- 1 mm) and weight was recorded using a digital scale (+/- 0.1 kg). Measurements were taken in light clothing and were used to compute body mass index standard deviation scores (BMI SDS) using the LMS method that accounts for growth and sex (Pan & Cole, 2002).

2.2.4 Measures of actual eating behaviour

Children were asked to manually serve themselves lunch onto the same plates that were used in the computerised portion-selection task. Children chose either penne pasta with tomato sauce (ED= 1.42 kcals/g) or macaroni cheese (ED= 1.51kcals/g) and then self-served a portion from a large bowl. These foods were chosen because they were also included in the computerised portion-size task and because they are homogenous, which enabled us to estimate calorie content of the amount served by weighing the plate after self-serving and the amount eaten by weighing the meal leftovers.

2.3 Procedure

2.3.1 Initial Testing

The initial testing took place in a classroom at the beginning of the school day and took around ten minutes per child. Children were tested alone. Testing included: confirming assent, followed by assessments of food liking and familiarity. Measure of height and weight were obtained. All testing was carried out by the research team.

2.3.2 Mealtime testing

At lunchtime, in a room adjoining the kitchen, separate from the classroom, the children reported their hunger and completed the computerised portion selection task. Participants were then given access to the pasta meal that they selected upon recruitment, and they were asked to self-serve an amount to consume. In each case, portions were created by selecting food from a large bowl. Participants ate their self-selected meals at a table with 7 of their peers, to replicate the school's typical communal lunchtime style that for some children involved hot meals whilst other children brought packed lunch. One difference was that the table had screens which prevented participants from seeing each other's portions. At the end of the meal, a measure of actual liking was taken, and the children's plates were weighed to measure any remaining food and to calculate the calories consumed. Researchers and a member of staff from the school were present during testing but did not comment or influence the children's serving and consumption directly.

2.3.3 Data analysis

One participant from the age 7/8 group was removed from analysis as they did not participate in the ad libitum meal, and two participants were removed from the age 10/11 group because their computer-based data failed to save.

Our first objective was to determine whether children in three age ranges have a conceptual understanding of portion size. To explore whether children manually select food portions that correspond with the amounts they subsequently consumed, correlations were conducted using Pearson's R between the food portions manually served and consumed.

To understand whether the portion size the child served differed by age, sex, child's hunger, the child's expected or the actual liking of the food, these factors were entered as variables in a bootstrapped multiple regression.

To understand how these same factors contributed to the amount consumed, they were entered along with the served portion size into a separate bootstrapped multiple regression.

Finally, to understand the impact of on portion size accuracy (the amount the child served, minus what they ate), a third bootstrapped linear regression was carried out to look at the impact of meal size predictors.

Next, the proportion of children plate clearing was identified, and Cramer's v was used to understand whether there was evidence of a difference in this behaviour in children of different ages.

Our second objective was to determine whether children have the capacity to use a computerised portion size tool. Pearson's correlations investigated whether the portions chosen on the screen correlated with those manually served.
The influence of the meal size predictors was also examined using a multiple linear regression. All regressions are bootstrapped with 95% confidence intervals in order to produce more robust effect estimates and confidence intervals.

A power calculation demonstrated that a sample size of 20 should give 90% power of determining a (non-zero) correlation between the computer and actual chosen portion size, using the 5% level of significance (one-sided test), assuming the correlation will be of similar magnitude to that found in adults (0.6) (Wilkinson et al. 2012). Calculated using G*power 3.0 software.

2.3.4 Deviations from protocol

The protocol stated that portion size data would be collected using the computer-based tool during an initial morning testing period, as well as at lunchtime. In line with the protocol, these initial data were collected but as no hypothesis was included and this work forms a separate piece of research (conducted for a Ph.D. project), these data are not discussed here.

Contrary to the protocol, we did not remove extreme responses. This decision was taken because a large number of outliers were observed and we reasoned that they should remain in order to obtain a more faithful estimate of the validity of the measures.

The protocol stated that the effect of age on portion size would be investigated. In the pre-registration we omitted to also include the effect of age on portion size accuracy, which has now been included in the analysis of this paper and labelled as *post hoc.* Further, relationships between the expected liking and served meal size were stated a priori in our registration. However, the relationship between expected liking and computer portion sizes was omitted, and so this has also been incorporated as a post-hoc analysis.

3 Results

3.1 Participant characteristics

Participant characteristics are detailed in table 1. Across age groups, participants' hunger and liking differed, with the two younger groups rating themselves as hungrier and liking the food more than the older group (see table 2).

Table 2. Participant summary statistics (mean and standard deviation)

	Total (n=76)	Age 5/6 (n=23)	Age 7/8 (n=22)	Age 10/11 (n=31)
Lunchtime testing hunger (SD)	82 (20)	90 (14)	88 (19)	74 (21)

0-100 mm VAS scale				
Expected liking of meal eaten (SD) 0-100mm VAS scale	82 (21)	83 (25)	84 (18)	80 (21)
Actual Liking (SD) 0-100mm VAS scale	85 (15)	85 (21)	89 (11)	82 (11)
Amount manually self-served (kcal) (SD)	388 (131)	396 (189)	413 (116)	365 (81)
Amount eaten (kcal) (SD)	328 (105)	294 (102)	346 (124)	365 (89)
Kcals left uneaten (SD)	60 (116)	102 (178)	67 (88)	23 (44)
Number of children who plate cleared (%)	45 (59)	10 (44)	10 (46)	25 (81)
Amount chosen on the computer screen at lunchtime, of meal eaten (kcal) (SD)	705 (358)	820 (383)	718 (406)	610 (280)
Discrepancy between meal manually served and that chosen on the computer screen at lunchtime (kcal) (SD)	317 (335)	424 (375)	305 (380)	246 (249)

3.2 Do children manually serve portions that correspond with the amounts they subsequently consume?

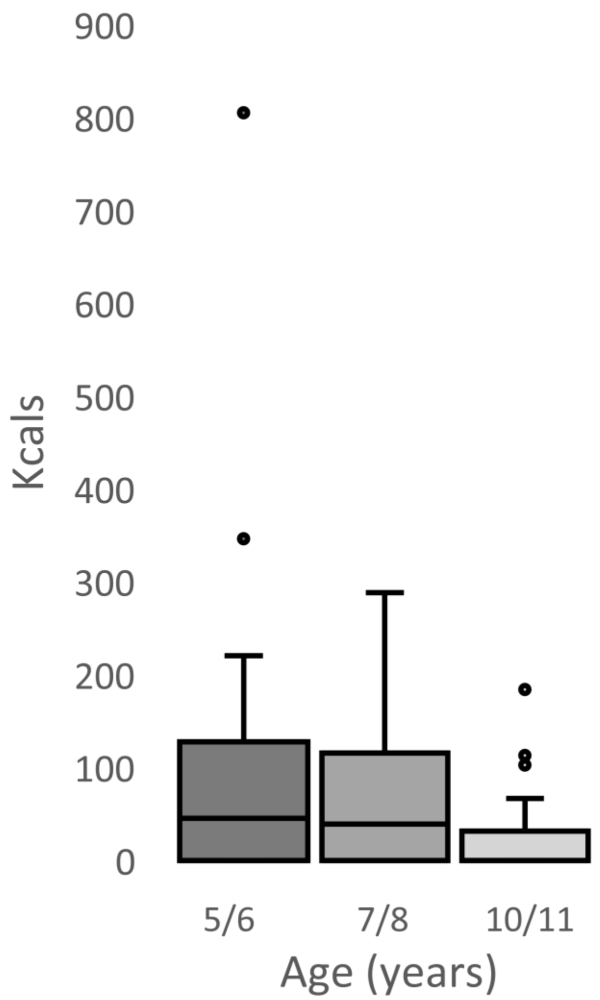
A few children (outliers) chose very large portions (see Figure 1). Nevertheless the size of the meals served (M= 388kcals, SD=131kcals) and eaten (M= 328kcals, SD= 105kcals) were broadly consistent with guideline intakes for a child's lunch (NHS, 2015). A positive correlation was found between manually served food portions and the amount eaten (r =.53, 95%CI [.34, .82, P<.001) indicating that many children were able to anticipate their likely food intake, prior to meal onset. There is evidence that exists in children age 5/6 (r =.41, 95%CI

[.12, .67], P= .01), aged 7/8 (r =.74, 95%CI [.44, .89], P<.001), and age 10/11 (r =.87, 95%CI [.73, .97], P< .01).

As outlined above, a further indication that children show adult-like portion selections would be if they demonstrated sensitivity to liking and hunger. In our sample, manual self-served portions did not correlate with expected liking (r= .02, 95%CI [-.23, .24], p=.88), actual liking (r= -.07, 95%CI [-.10, .22], p=.57) or hunger (r= .16, 95%CI [.01, .31], p=.16).

Linear regression confirmed that the child's serving size was not influenced by age (t(68)= -.50, p=.59), sex (t(68)= -.77, p=.40), expected liking (t(68)= .08, p=.94), actual liking of the meal (t(68)= .41, p=.52), their hunger rating (t(68)= .1.05, p=.16), meal choice (t(68)= .35, p=.71) nor BMI-SDS (t(68)=.1.76, p=.32).

Figure 1. Single whiskered boxplot demonstrating the discrepancy between kcals manually self-served and eaten by age group



Interestingly, when these variables were considered along with the amount of food that a child self-served, the combination of age and amount self-served explained 33.2% of the variance in amount consumed. As the child age group increases by one group (e.g., age 5/6 to age 7/8), the amount eaten increases by 35 kcals ($t(68)=2.6$, $p=.02$). As the portion size served increases by one unit (1 kcal), the amount eaten increases by .44 kcal ($t(68)= 5.5$, $p=.04$). Sex, ($t(68)= .06$, $p=.95$), expected liking ($t(68)= -.27$, $p=.78$), actual liking ($t(68)= .37$, $p=.72$), hunger ($t(68)= 1.20$, $p=.23$), meal choice ($t(68) = -.87$, $p= .47$) and BMI-SDS ($t(68)=-.85$, $p = .40$) do not contribute.

It was acknowledged that an important marker of a child's understanding of portion size, was the precisions with which they served a portion that they went on to eat. Therefore, post-hoc, we explored the importance of factors influencing children's portion size accuracy (the amount of food served minus the amount of food eaten). Our regression model revealed that age contributes 9.4% of the variance in portion size accuracy ($t(68)= -2.3$, $p=.02$), while sex ($t(68)= -.55$, $p=.52$), expected liking ($t(68)= .26$, $p=.75$), actual liking ($t(68)= -.01$, $p=.99$), hunger ($t(68)= -.24$, $p=.71$) meal choice ($t(68)= .9$, $p=.39$) and BMI-SDS ($t(68)= 1.79$, $p=.41$) contribute very little.

Finally, 59% of the children cleared their plate (see Table 1), this tendency was especially evident in older children (81% of 10/11-year olds plate cleaned; effect of age, $X^2(2) = 9.98$, $p=.007$, Cramer's V=.36).

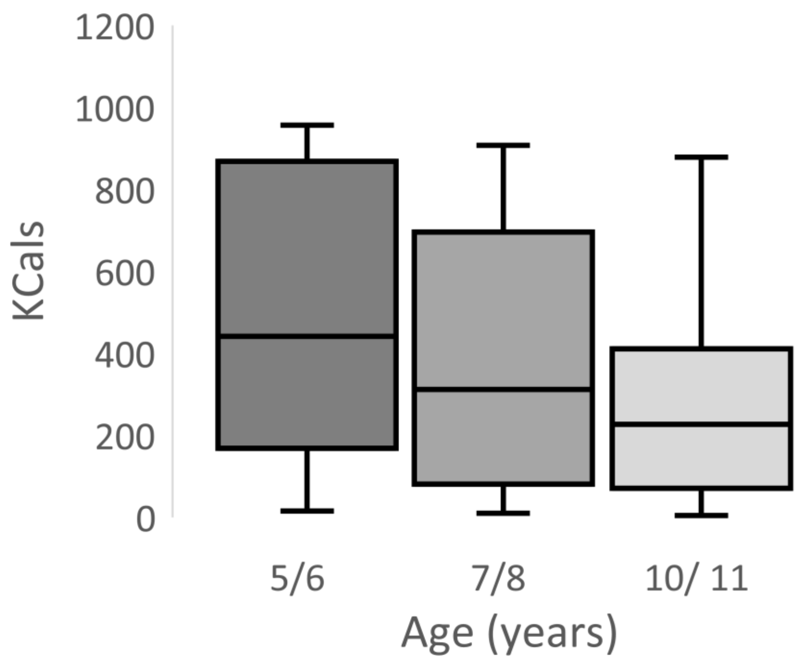
3.4 Using the computerised portion size tool

3.4.1 Are children able to use a computerised portion size tool to demonstrate the portion size they will manually serve?

The portion sizes chosen on the computer at lunchtime correlated with the amount manually served ($r=.34$, 95%CI [.07, .55], $p<.01$). Figure 2 details the discrepancy between the lunchtime computer and manual food portions in the three age-groups.

There is weak evidence of a correlation between a child's age and their accuracy at choosing a portion size on the screen that represents the portion they serve, ($r =-.221$, 95%CI [-.41, -.01], $p= .055$), where a smaller discrepancy is seen in the older children. We do not see a correlation between children at age 5/6's portion sizes on the computer and those manually served (r =.21, 95%CI [-.18, .56], p= .18), but we do see this correlation at age 7/8 (r =.45, 95%CI [.24, .64, P< .01) and 10/11 (r =.50, 95%CI [.27, .70, P< .01).

Figure 2. Boxplot demonstrating discrepancy between kcals chosen on the computer and calories served manually during a meal



3.4.2 Computerised portion sizes and the relationship with hunger and liking

Post-hoc, a regression model was run to look at portion size accuracy. This explored the similarity between the portion size selected on the computer and the actual served portions of pasta. The model explained 13.9% of the variance in children's accuracy, with higher correspondence in children who were hungrier (t(68)=2.19, p=0.04). This may be due to hungrier children being more likely to plate clear.

Age (t(68)= -.82, p=.42), sex (t(68)= -1.8, p=.07), and liking of the meal (t(68)= 1.9, p=.15) did not influence child's accuracy.

Discussion

This study sought to determine whether children have a conceptual understanding of 'portion size.' Specifically, whether they are able to form a mental representation of the amount that they will eat in advance of a meal and whether they can express this by manually selecting food portions from a serving bowl and by using a computerised portion size tool. Our findings indicate that manual portion-size selection can be observed in all age groups, including in the five-and-six-year olds and that children from age seven can use a computerised portion size tool, in as much as their 'virtual' responses correlate with their manual portion selections. Moreover, we see the correspondence between manual portion selection and actual intake (the portion selection accuracy) improves with age. There is of course, the possibility that this improvement is also influenced by older children's greater awareness of being 'tested' and a greater social desire to be correct, which may drive an improvement in their memory and recall of the portion sizes and therefore an improvement in their performance.

Broadly, our data also confirm that children from the ages of 5/6 can self-serve a portion size that is in line with both national recommendations (NHS, 2015) and their own eating behaviour (self-served portions correlate with what is eaten). Overall, these findings indicate that children should be encouraged to self-serve their own portions (consistent with current UK guidelines). However, we also observed large individual differences, with some children at all ages apparently lacking the conceptual ability or training that is needed to select a portion size. The reason for these differences remains unclear but they suggest that simple health messaging around the importance of self-selection may not be appropriate for all children. There is also a possibility that some children might benefit from more tailored support, which is an area in need of future research.

In addition to age-related improvements in manual serving accuracy, we also observed an increase in the tendency to plate clean. In adults, plate clearing levels of around 90% have been observed (Wilkinson et al., 2012), and it would appear that our data match a developmental trajectory that has been observed elsewhere (McCrickerd et al., 2017). Further, the parallel age-related correspondence between serving accuracy and plate cleaning is consistent with the proposition that plate-cleaning reflects a capacity to accurately anticipate and self-serve an appropriate portion size, before a meal begins (Brunstrom, 2014).

However, we cannot say with any certainty that social influences, such as feeding practices, are not driving this increase in plate cleaning. Future research should explore how plate clearing is influenced by socioenvironmental factors, and whether children show different plate clearing behaviours towards pre-plated meals.

In this study, neither hunger nor liking were associated with manual serving size. This is in contrast to previous research suggesting that children's innate reliance on hunger and satiety signalling for portion size selection drives accuracy (Fox et al., 2006; Rolls et al., 2000; Westenhoefer, 2001). This could be because of a high homogeneity of responses in our data that prevents the exposure of a relationship with intake. We see that children rated themselves as very hungry, with a small standard deviation and children also chose to eat a food that was liked, meaning there is little variability in liking to allow an additional effect on portion size to be visible. When the analyses were run on the portion sizes selected on the computer tool that included a broader range of foods, a relationship with both hunger and liking was demonstrated. Whilst this could demonstrate a relationship that was formally not exposed due to the homogeneity of the data, due to the different methodology (screen compared to real-life) we cannot say this with certainty. The lack of an effect of these two variables may also be due to measurement error. Both hunger and liking were measured using a VAS scale, which in other research has been found to elicit polarised answers from children, indicating that the scale lacks sufficient sensitivity (Porter et al., 2017).

We also acknowledge that, unlike the studies using the tool in adults (Wilkinson et al., 2012), the children were not allowed to self-serve a second portion of the food in the dining hall. This decision was made to maintain external validity of the study as it more accurately reflected the usual dining experience at the school where data collection took place. Testing within an *ad libitum* setting, where children can re-visit the bowl to serve themselves more food, might generate a different outcome. We also acknowledge that no correction for multiple comparison was made during our analysis. In addition to refining our methods, an obvious next step would be to look at how portion selections associate with BMI-SDS. Previous work would seem to indicate that children with a higher BMI respond differently to portion size (Fogel et al. 2020; Mooreville et al., 2015) however, the majority of our participants were of normal weight.

While the results suggest that the computerised tool detects *relative* differences in portion size at all ages (children who manually served a large manual portion size also chose a large portion using the computerised portion size tool) there appears to be a large absolute difference. However, in some children, including some of the youngest children, this difference was small and others, including some of the oldest children, it was very large (see Table 2 and Figure 2). For comparison it would be helpful to know how this discrepancy compares to an adult population. One explanation might be that the computer-based portion was perceived to be smaller, partly because the screen displayed 'smaller than life' portions. To help to mitigate this problem, following previous 'paper-based approaches' (Nelson, 1997), we recommend incorporating cutlery or other items of known size into the food images. More generally, efforts of this kind are important because we and others (Foster et al., 2008; Livingstone, Robson, & Wallace, 2004; Vereecken, Dohogne, Covents, & Maes, 2010) recognise the potential benefits of using a portion-selection tool in clinical assessments, and such tools have continued to be valued for their use as pragmatic alternative to group-level observation-based eating studies in children (Foster et al., 2008). We see an age effect on children's accuracy at serving portion sizes that they go on to eat. A possible explanation is that children's cognitive and spatial abilities develop throughout childhood, which promotes greater accuracy when selecting portion sizes, both manually and on a screen. Jean Piaget's theory of cognitive development (PIAGET, 1962) suggests that between the age of 7-11, children reach the 'concrete operational stage' where children acquire cognitive skills such as the conservation of mass and volume – the understanding that an item is of equal quantity despite changing its form develops. For example, that water poured from a tall narrow glass into a short wide glass is the same quantity of water, despite the appearance of the water level decreasing. We hypothesise that children who have reached this critical stage may have an enhanced ability to demonstrate portions on a computer screen and suggest that further research to understand the relationship between portion size and children's cognitive development may help to develop age-appropriate portion guidelines.

In summary, whilst it seems that the majority of children are able to self-serve reasonable size portions for themselves, parents and clinicians should consider the individual child when recommending this approach, as individual differences are apparent. The authors acknowledge the limited sample size and restricted age-groups tested, and recommend that further research is needed to determine how cognitive development and social environment affect children's responses to portion size. In terms of potential clinical applications of the computerised portion size tool, we conclude that individual-level discrepancies with manual measures are a concern, but with further development we see considerable potential for its use in a clinical setting to assess children's portion sizes and to aid conversations about healthy portion size, both with parents and their children. A potential future step would be to understand whether estimation errors occur consistently over time. Whilst between-participant comparisons remain imprecise, if errors occur consistently, the tool may offer opportunity to measure changes within an individual over time, which is of clinical relevance.

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Author contributions

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