Predictors of vegetable consumption in children and adolescents: Analyses of the UK National Diet and Nutrition Survey (2008-2017).

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Abstract

Children's vegetable consumption is generally below national recommendations in the UK. This study examined predictors of vegetable intake by children aged 1.5-18 years using counts and portion sizes derived from four-day UK National Diet and Nutrition Survey food diaries. Data from 6,548 children were examined using linear and logit multilevel models.

Specifically, we examined whether demographic variables predicted vegetable consumption, whether environmental context influenced portion sizes of vegetables consumed and which food groups predicted the presence (or absence) of vegetables at an eating occasion (EO). A larger average daily intake of vegetables (g) was predicted by age, ethnicity, equivalized income, variety of vegetables eaten and average energy intake per-day (R^2 = 0.549). At a single EO, vegetables were consumed in larger portion sizes at home, with family members and at evening mealtimes (Conditional R^2 = 0.308). Within EOs, certain configurations of food groups such as carbohydrates and protein predicted higher odds of vegetables being present (OR: 12.85, 95% CI: 9.42–17.54); whereas foods high in fats, sugars and salt predicted a lower likelihood of vegetable presence (OR: 0.03, 95% CI: 0.02–0.04). Vegetables were rarely eaten alone without other food groups. These findings demonstrate that only one portion of vegetables was eaten per-day (median) and this was consumed at a single EO, therefore falling below recommendations. Future research should investigate ways to encourage vegetable intake at times when vegetables are not regularly eaten, such as for breakfast and as snacks, whilst considering which other, potentially competing, foods are presented alongside vegetables.

1. Introduction

The habitual daily consumption of vegetables contributes towards a balanced and healthy diet, in line with UK government recommendations to eat five portions of fruit and vegetables (FV) per-day [1]. The five-a-day message is a practical compromise since research suggests that health benefits are observed in dietary intakes of up to 10 FV per-day [2]. In 2018, less than 18% of UK children aged 5-15 ate five portions of FV, with the average intake at three portions per-day [3]. Girls and younger children tend to have larger and more frequent intakes of vegetables than boys and older children [4], and families with lower socio-economic status and low availability or accessibility to vegetables at home have been linked with reduced intake [5]. Additionally, children with eating traits such as high food enjoyment and low food neophobia have associated increased intakes of vegetables [4], whereas children with fussy eating traits consume few vegetables [6]. Low intakes of vegetables track consistently across children's development [7; 8].

For adolescents, many of the same reasons for not eating vegetables apply [9], as well as issues around image and gender identity [10]. Furthermore, FV are more nutrient dense than other food groups, but less energy dense, leading to weaker feelings of perceived "fullness" or satiation [10], and therefore higher energy dense foods may be preferred to vegetables. Thus, for older children social influences [11] and energy density of vegetables may add to explanations of low vegetable intake.

Research on the environmental context of eating suggests that vegetables are most often eaten as part of a composite meal [12] and that this vegetable consumption at home during family mealtimes is associated with improved dietary quality [13]. At mealtimes, children are often served the same foods as the rest of the family [14] and parents have the opportunity to model intake, which is positively associated with child and adolescent vegetable intake [15]. Furthermore, since fewer vegetables are eaten than recommended, making changes to serving sizes at mealtimes has long been a strategy to change intake for FV. Research that has increased vegetable serving sizes within a meal demonstrates increased intake of vegetables in children [16; 17], though this method can also produce increased plate waste. Additionally, overall vegetable intake may be stimulated by variety. Offering a variety of vegetables has been shown to increase consumption [18], but this is mitigated by the presence of other food items [17; 19].

Little is also known about the relationship between the environmental context, portion sizes and other foods present at separate eating occasions (EO) on children's habitual daily

intake of vegetables. This has been investigated for palatable, high energy density food items [20], showing that age, time of day and context (TV on, at home, out of home) were important determinants of portion size in children and adolescents, however these relationships have not been determined for vegetables. Therefore, the present study investigated predictors of vegetable intake based on environmental context, time of day and the types of foods that vegetables are eaten alongside. Vegetable consumption is examined without fruits in order to identify differences in intakes and eating contexts compared to previous research examining both food groups together. It is important to examine vegetables separately as vegetables are often rejected or not eaten by children [21; 22] despite having potentially greater health benefits than fruit [23; 24; 25; 26]. Therefore examination of vegetables alone may provide more specific insights to children's eating habits compared to fruits and vegetables when examined together. This study examined characteristics that predict vegetable intake in children and adolescents aged 1.5-18 years, by conducting secondary analysis of data on the UK National Diet and Nutrition Survey (NDNS). This is a nationally representative sample of four-day food diaries collected between 2008 and 2017. We examined whether daily intake of vegetables could be predicted by demographic variables, if the environmental context of an EO influenced whether, and how much, vegetables were eaten, and which food groups predict the presence (or absence) of vegetables being eaten in an EO.

2. Methods

2.1. Sample.

Secondary data analysis was conducted utilising years 1-9 of the UK National Diet and Nutrition Survey (NDNS) [27] collected between 2008 and 2017. The NDNS is a rolling cross sectional survey that runs continuously throughout the year to collect detailed information on food consumption and nutritional intakes of the UK population. The survey aims to include around 1000 participants total each year from England, Scotland, Wales and Northern Ireland, with an equal split of 500 children (1.5-18 years) and adults (19+ years). Due to some households only containing adults, at many addresses only a child participates in order to boost the number of children in the sample to match that of the number of adults. The sample is drawn from the postcode address file of all private households in the UK. Full details of the NDNS design and sampling procedure are reported elsewhere [27].

Data collection for the NDNS is composed of interviewer visits and a nurse visit. During interviewer visits, data is collected from face-to-face interviews, self-completion questionnaires, a four-day food diary and height and weight measurements. This is followed

by a nurse visit which involves taking physical observations and blood samples of the participant, as well as detailed information regarding medication and dietary supplements taken. Field work is conducted throughout the year, to ensure an even representation of months and days of the week. Therefore, the data includes potential seasonal variations in food intake, as well as differential intakes during the week compared to weekends. The current analysis considers only data from the interviewer stage of the survey and includes only the subsample of children aged younger than 19 years (n = 6,548, female = 3,197). Full participant characteristics are reported in **Table 1.**

2.2. Dietary Data

During the interviewer phase, the NDNS collects a four-day estimated food diary to observe dietary habits. Participants are asked to write down everything that they eat and drink over this period, along with the time, who they are with and where they are. Children aged 13 years and older can complete their own diary, however for children 12 years and under, a parent/carer is requested to complete the diary. The diary is completed at the time of eating rather than from memory and records should indicate how much food was consumed (not amount served or including leftovers). To assist with amounts of each food eaten, participants are asked to describe food consumption in terms of weight (g) or household measures (e.g. tablespoons, teaspoons, cups, slices etc.). When reviewing the diary, children are additionally asked to select pictures of portion sizes served and amount of leftovers using the Young Person's Food Atlas [(28)], to complement reported portion size data. To further supplement food data, participants are instructed to keep food packaging and labels with weights and nutrient information for each food. To ensure compliance with this procedure and to allow the participant to ask questions, the interviewer conducts a mid-diary visit, before returning at the end of the four days to collect and review the diary. Only children that completed three or four diary days were included in the survey (3 days n = 121, 1.85%, 4 days n = 6,426, 98.13%).

Diaries were coded by trained coders and editors from the NDNS research team and all food intakes were entered into a modified Diet in Nutrient out (DINO) [(29)] assessment system. Each food was given the corresponding food code and portion code from the NDNS nutrient databank. For composite recipes, each food component was assigned a food code. If portion sizes were reported as a weight, this was directly input into the DINO. Alternatively, if the portion size was described as a household measure, the appropriate weight for each type

of food given the measure was selected. Where foods were consumed at school, portion sizes and nutrient information were determined from data collected by school meal surveys.

For this study, all food data were selected from the full NDNS dataset (Years 1-9, n = 6,548). Beverages, sweeteners and supplements data were not included in analyses. This is because the NDNS reports sweeteners and supplements in terms of a base unit rather than grams and beverages impact on the overall weight and energy intake at each EO (e.g. water provides no energy content, whereas alcohol provides a large amount of energy). However, beverages were still included in the total energy intake per day for each individual. All other potion sizes of foods were given in grams, which were converted to energy intake by the NDNS research team.

2.3. Variables

For each participant, to create the outcome variables of interest, the mean number (absolute count) of vegetables eaten per day was derived from the food diaries. Similarly, the mean portion size (g) of vegetables that were eaten per day was also calculated. Each EO was coded for inclusion of vegetables, and the total portion size (g) of vegetables consumed in each EO was also calculated.

Within the NDNS dataset, age in full years and gender were recorded for each participant, as well as the diary month and day number of the diary (1-4). Age was centred, but not scaled, to make parameter estimates easier to interpret. Age squared was also included in models to examine the non-linear fit of age. Participant's ethnic group, whether they were vegetarian or vegan, BMI category and equivalized household income were also included. BMI was categorized within a range of weight categories from normal weight (including underweight), to having overweight and obesity. These categories utilise the BMI WHO cut-offs (85th/95th centile for 2–3-year olds (inclusive) and UK90 for 4–18-year olds. For the 435 children with missing BMI values, these were assigned as healthy weight. Z-score equivalized household income (a measure of household income that is derived from the size of the household and the relationships between the people within) was included, however, this was missing for 526 (8%) participants. We assume that the data is missing at random because the chance of observing this variable (equivalised income) may depend on its value, as adults were asked about income during interview. Therefore, missing values were estimated using multiple imputation [30]. Demographic variables of adult employment status, number of children under-18, ethnic group and known equivalized income values were input into a classification and regression trees (CART) algorithm to impute the missing data.

To account for seasonal effects on vegetable consumption, the months of November, December and January were classed as "Winter", February, March and April as "Spring", May, June and July as "Summer" and August, September and October as "Autumn". Where the EO took place and who with were collapsed into fewer categories [20; 31]. Places were categorised as "at home" for any location within the home, "at school or work" included all locations at school (as well as locations in the workplace for some older children in the sample), "food outlet" including restaurants, cafeterias and any place that food can be brought outside of the home, "on the go" for foods that were consumed outside, on the street or in transportation, "leisure" including leisure centres and leisure activities, and all other places were categorized as "other". Similarly, categories for who the individual was eating with were reduced to eating "alone", "with parents only", "with children only", "with friends only", "with multiple groups-family and friends" and all other EOs were categorised as "other". Lastly, food group categories were compressed to those representing mainly "vegetables", "fruit", "carbohydrates" (including rice, pasta, bread, cereal etc.), "protein" (meat, fish, eggs and nuts and seeds), "dairy" (not including milk as this was categorised as a beverage) and "fats, sugar and salt (FSS)" (including foods such as puddings, pastries, sweets, biscuits, chocolate, crisps and savoury items). These food groups were guided by those described in the UK Eatwell guide [32]. Fats and oils, mainly including butter and cooking oils, were not used in any analyses.

2.4. Data analysis

NDNS data sets for years 1–4 (2008/09–2011/12), years 5–6 (2011/12–2013/14), years 7–8 (2014/15–2015/16) and year 9 (2016/2017) were combined. These datasets were weighted to adjust for differential selection probabilities, differences in sample selection between years and non-response to certain NDNS procedures. Weights were calculated for all children (18 years and under) in the sample using NDNS instructions [27], and these weights were incorporated into all analyses. Individual weights for each data collection period (i.e. years 1-4, 5-6, 7-8 and 9) were summed separately. Individual weights were then divided by the sum of weights for that data collection phase and multiplied by the sum of all phase weights. Finally, this was multiplied by the number of years in that phase/total number of survey years (e.g. years 1-4 would have been 4/9, as there were 9 total years). We then checked that the SD = 1 and the Mean = 0 of all weights combined.

EOs that were within 15-minutes of each other, in the same place and with the same people were combined into a single EO [20; 31]. For determining average daily absolute count and average daily consumption (g) of vegetables in the individual, data were analysed at the person level (n = 6,548) using linear models. Two multiple regression analyses were conducted predicting daily vegetable consumption in both counts and total portion size. Demographic variables including age, age^2, gender, ethnicity, equivalized income, parental employment status and BMI category were used as predictors, along with vegetable variety index (number of different vegetables eaten across diary days), vegetarian or vegan status, season (winter, spring, summer and autumn), year of NDNS survey and number of children in the household were included in the model.

For analyses to determine the outcome of vegetable portion size consumed at a single EO, portion size of vegetables (g) was totalled for each EO. Data were analysed only for EOs that included vegetables (n = 25,059), using multi-level linear models. The intercepts were allowed to vary by participant. This analysis included the predictor variables age, gender, BMI category, weekday, location of meal, who with, time of day, daily energy intake (kcal) and vegetarian or vegan status, along with amounts (g) of each food group in the meal and interactions of each predictor with age.

Lastly, analyses were conducted to determine which food groups predict the presence of vegetables within an EO. Data were analysed using all EOs, apart from those that only included vegetables (n = 124,023), using multi-level logit models. Binary variables were created for whether the EO contained each food group type, and main effects and interaction terms for each food group were added to the model.

For all models, data were split into model building and test datasets (all 50:50 split) using different pseudo-random seeds for each analysis. All predictors that significantly added to the model in the model building phase were included in the model testing phase, whereas predictors that did not add to the model were left out of the testing phase. An alpha level of .01 was used to determine significant predictors. Only results of test datasets are reported here as the predictors all had significant main effects in the model building samples.

Data analyses were conducted using RStudio 1.1.383, with R (version 3.5.2, Eggshell Igloo), tidyverse 1.3.0, haven 2.2.0, lme4 1.1-21 and lmerTest 3.1-0.

3. Results

Across the four-day food diaries, there were 307,205 food entries (after removing beverages, sweeteners and supplements), for 6,547 children (one person did not consume any food, only beverages, during all days of the diary and therefore does not appear in any analyses). Of these, 6,184 children consumed at least one vegetable 54,989 times. There were 116 vegetarians and 5 vegans in the sample. Food entries made up 124,436 unique EOs, 25,059 of which included at least one vegetable. However, in only 413 EOs were vegetables eaten alone, with 489 different counts of vegetables eaten. When vegetables were eaten on their own, raw carrot was the most popular (n = 116), followed by raw cucumber (n = 61) and raw tomatoes (n = 44). Children consumed vegetables on average 8 times over diary days (Mean = 8.40, Median = 7, SD = 7.01) with an average variety intake of 5-6 different types of vegetable (Mean = 5.59, Median = 5, SD = 3.79). A total of 58 different types of cooked (count = 37,880) and 47 different types of raw (count = 17,109) vegetables were eaten by the participants. **Table 2.** presents the most commonly consumed vegetable types eaten both cooked and raw.

3.1. Demographic predictors of vegetable intake

Individual intake of vegetables, average daily absolute counts and average daily weight (g) of vegetables consumed were examined. Regression analyses revealed that older children ate fewer absolute counts of vegetables per day, however when they did eat vegetables, they had larger portions. Ethnicity also affected both amount and absolute counts of vegetables eaten, with white British children tending to eat fewer absolute counts of vegetables than BAME children, yet consuming a larger amount of these vegetables per-day. Additionally, vegetarians and vegans (although small in number) ate more vegetables and had a higher intake than those classed as neither and eating a wider variety of vegetable types in general increased both the count and gram intake of vegetables per-day. Lastly, average daily energy intake suggests that children who consume more energy daily generally tend to eat larger amounts of vegetables per-day, although this did not predict counts of vegetables eaten per-day. Gender of the child, season (time of year), year of NDNS survey and number of children in the household did not significantly add to the model and neither did any interaction terms. **Table 3.** shows the model estimates for each predictor on vegetable intake for the individual. **Figure 1.** displays the median amount of vegetables (g) that were eaten

per-day for each age group. This suggests that only one portion of vegetables is achieved by children per-day.

3.2. Frequency of vegetable consumption

Table 4. reports the frequency (with percentage of total absolute counts) that vegetables were eaten by location, with whom eating occurred and time of day. It also reports the number of EOs that included vegetables and the total number of EOs for comparison. Vegetables were consumed mostly at home, with family members at typical dinner (5pm to 8pm) and lunch (12pm to 2pm) times. School (and workplace) was the location with the second highest intake of vegetables, although intake was far less frequent than that at home. Vegetables were generally not eaten on the go, at food outlets or at places of leisure. Children also ate fewer vegetables when eating alone or with other children and at times of the day not associated with lunch and dinner. However, there was a small peak in eating vegetables between 2pm to 5pm, in the transition period between typical lunch and dinner times.

3.3. Predictors of Portion size (g) of consumed vegetables

To examine if environmental features influenced portion sizes of vegetables (g) at each EO, predictors were entered into a linear multi-level model as fixed factors, with the individual as a random factor. The model shows that the average portion size of vegetables (when they are eaten) is 40 g. It is demonstrated that larger portion sizes of vegetables are eaten as the child becomes older, when vegetables are eaten at home and at the weekend. Total vegetable portion sizes are 20-40 g smaller outside of the home depending on location, even at school. Children ate larger portions of vegetables at typical evening meal times between 5pm to 8pm and vegetable portions were also slightly larger if the child ate a wider variety of vegetables over the NDNS diary period. Interactions between age and location, age and with whom vegetables were eaten as well as age and time of day all significantly improved the model and so were retained in the final model. Gender and BMI category did not add to the model to predict vegetable portion sizes. Overall, 82% of the variance explained by the model is due to within person variation, suggesting that vegetable portion sizes vary little between children, but vary to a larger degree within an individual based on the context of the eating situation. The final model with all predictors and interactions is presented in **Table 5**.

3.4. Food groups as predictors of vegetable presence

To explore whether certain food groups and combinations of food groups predict vegetable presence (or absence) within an EO, each EO was classed as either including vegetables or not. All other food groups were likewise classed as either being present in the meal or not and were used as binary predictors of vegetable presence in the meal. **Table 6.** presents findings from a multi-level logit regression model and reports odds ratios of vegetables being present for each combination of food groups in an EO. The results illustrate that all food groups alone (carbohydrates, protein, dairy, fruit, and FSS items), without further information of other combinations of food groups present, predicted a lower odds of vegetables being present within the EO. However, for different combinations of these food groups, the likelihood of vegetables being present varied. When carbohydrates were eaten together with protein at an EO, it was 12 times more likely that vegetables were present. Similarly, combinations of protein with dairy and carbohydrates with fruit predicted a higher odds of vegetables being present. In contrast, some combinations predicted the absence of vegetables. EOs that included FSS food items unaccompanied by a carbohydrate or protein were 33 times less likely to contain a vegetable. Together, combinations of food groups and individual variability between children explains 57% of the variance in the model for when vegetables are likely to be present. Of this variance explained by the model, 87% is due to within person variation, suggesting that combinations of food groups that predict the presence (or absence) of vegetables vary little between children. There is a larger degree of variation within individuals based on the different food groups eaten.

4. Discussion

This study conducted secondary analyses of the UK NDNS dataset years 1-9 to investigate predictors of vegetable intake in children and adolescents. Findings indicate that daily vegetable intake (g) is predicted by age, ethnicity and variety of vegetables eaten. These vegetables are most often consumed at home, with family members and at times that are usually associated with meals in the evening (5pm-8pm) and early afternoon (12pm-2pm). When vegetables are eaten, they are rarely eaten alone, do not often meet recommended portion sizes and are likely to be eaten alongside foods that are carbohydrates and proteins, but much less likely to be eaten alongside foods that are high in fats, sugars and salt.

Age was an important predictor of both daily intake and portion sizes of vegetables, indicating that older children tend to eat larger amounts of vegetables than younger children. The median amount of vegetables (g) eaten per-day for each age group was only enough

weight to equal one vegetable portion. This was found again when examining portion sizes of vegetables when they were eaten at a single EO. The intercept for vegetable portion size per EO was between 26-55g and estimates of portion size increased by 2-3g for each additional year of age. This suggests that on average, only enough weight for one vegetable portion was eaten at an EO, and this portion is likely to be the only portion consumed per-day. It is also important to note that portion sizes in this study were cumulative of all vegetables eaten within the EO, and not for each vegetable served, meaning that this portion may be comprised of multiple vegetable types. Therefore, not enough variety of vegetables are consumed by children, as well as amount, to meet recommendations for daily intake.

Government recommended vegetable portion sizes for children vary by age, body size, activity levels and the food type. For 4-10 year olds, the guidelines are between 40-60g for a portion of raw or cooked vegetables, and 80g for 11-18 year olds [33]. Although between the ages of 3 and 18 years we observe an estimated 45g increase in vegetable intake at an EO, we did not observe an increase of 40 (g) in portion size for children between 10 and 18 years (the age at which the portion size recommendation changes). This suggests that although older children ate a larger amount of vegetables, this was rarely at the recommended level. However, due to the observational nature of the data, it cannot be commented whether vegetable intake was low because serving sizes were small, or whether serving sizes were larger but not eaten, therefore producing wasted or left-over food.

Individual food groups were good predictors of whether vegetables were eaten or not. We found that vegetables were less likely to be eaten alongside foods high in FSS, ingredients associated with high palatability. This is consistent with previous research interventions which have suggested that vegetables were often not eaten due to competition from other foods [34; 35; 36]. However, it does not explain why vegetables are more likely to be eaten with carbohydrates and proteins. It is possible that the configuration of different foods together either increases or decreases vegetable intake. As the majority of vegetable intake comes from composite meals made of several foods [12], a finding that we replicate in this study, certain flavours or textures may enhance vegetable intake or vegetable taste in meals [37] (e.g. by masking or enhancing the taste utilising food-food interactions), and decrease intake in other meals [38] (e.g. because other foods are more palatable). Whilst it is not possible to provide evidence for this explanation using diary data, in future research it may be important to consider the potential competition of other food groups present when promoting vegetable intake by children. However, a further explanation for these food groups being commonly eaten together is due to cultural habit. This is regarding how meals are constructed

in the UK and how parents present foods to their children within familiar meals, recipes and composite foods. If children are not presented with vegetables alongside fruit, or foods high in FSS, then children may never have the opportunity to eat these foods together, which may be reflected in these findings.

Vegetable portion size was predicted by EOs occurring in the early evening, which is likely because the evening is when the majority of daily energy intake is consumed [39]. Vegetables might also be eaten more often within meals as part of a planned and prepared meal [40]. This was evident as vegetables were eaten alongside cooked items high in carbohydrates and proteins (e.g. pasta, potatoes, meats, fish). Additionally, vegetables were rarely eaten at other times of day or on their own, suggesting that vegetables are not usually eaten as snacks. Overall, vegetable intake appears to require planning since they need to be prepared, chopped, peeled and cooked. Since preparation takes time, and parents are often responsible for children's intake, the time available for parents to prepare these foods may be in the early evening, after the child's school and parental work commitments [40]. This may also partly explain the weekend effect, why more vegetables were eaten on the weekend compared to weekdays, as there may be more time available for planning and preparation of meals. However, this does not explain smaller vegetable portion sizes at school.

Interestingly, although the proportion of meals including vegetables at school was similar to that at home (20% of total EOs at school included a vegetable), vegetable portion size during EOs in school was much lower than that at home. Given the limited opportunities to eat at school (mainly lunch and break times), this could mean that children do not have the opportunity to eat vegetables at schools, either through packed lunches [41] or school meals [42], or that children do not eat vegetables served to them at school [43]. Certain age groups are supported in the UK for food intake, such as free school meals for 4-6 year olds. The UK also has a school FV scheme [44] where 4-6 year olds are entitled to a free piece of fruit or vegetable per day. Yet, we found little evidence of eating recommended portion sizes of vegetables at school. One reason for this could be that these schemes are not available to all age groups, though it is important for all age groups to eat FV regularly. Secondly, fruit is selectively chosen when FV are offered in class [45]. Therefore, simply offering vegetables to children as a snack at school is not enough to encourage intake and this may need to occur alongside a tailored intervention [46; 47; 48].

Eating vegetables mostly at home in the early evening accords with findings associating dietary quality with family mealtimes [13] and children eating the same foods as their parents [14]. We found that vegetable consumption occurred mostly with family,

including parents and multiple groups of family members and friends. Given that vegetable portion sizes generally increased with family members present compared to eating alone, this illustrates the importance of social learning [11; 49]. Suggs et al. [49] also found that most vegetable intake for Swiss children occurred at home during family meals using seven-day food diaries. Their conclusion was that eating was better for children at home with the family, meaning that this location has a positive influence on children's eating behaviours and diet. As children spend much of the day at school and parents have many other responsibilities such as work, this conclusion could add further responsibility onto the parents to provide all recommended portions of vegetables for children per-day. Since our findings suggest that vegetables are mainly eaten at mealtimes, this means that children would have to eat at least three recommended portions of vegetables in one sitting (assuming the other two portions are fruit and eaten outside of mealtimes). Yet, we found that only enough for one portion of vegetables is usually eaten at a single EO. Therefore, promoting vegetable intake outside of family evening mealtimes, such as at breakfast, as snacks and in schools at lunch times (where average portion size intake is lower than at home) could be an appropriate solution. Furthermore, if child preference is for smaller vegetable portion sizes [50], eating vegetables in small portions throughout the day may be a more suitable alternative for children, than having all recommended portions in one meal.

For children under 10 years, the importance of context for eating FV has previously been highlighted within the NDNS dataset [51]. However, differences between the current and previous study are likely due to inclusion of fruit intake. Findings from Mak et al. [51] show that fruit intake is more likely to occur outside of the home, meaning that there may be different contexts for eating FV. As we found no clear relationship of eating FV together, there is reason for assessing intake of these foods individually. Fruit is often eaten at different times, including as a snack or after meals as dessert [52], but generally not within composite meals [12]. Therefore, it has been suggested that fruits could be targeted separately from vegetables in national campaigns [53]. This may help to promote the importance of increasing amounts of vegetables eaten daily, as fruit intake is usually higher than vegetable intake in children [22]. Few countries, such as Australia and Netherlands have implemented this separate message with 'Go for 2 & 5' and '2+2' campaigns respectively.

4.1. Strengths

A multiple perspective approach to examining vegetable consumption patterns in children was taken. Previous studies have highlighted numerous predictors of vegetable

intake, but seldom use national dietary data to observe eating habits further than asking whether children meet the five-a-day guidelines. The current study not only looked at average intake and absolute counts of vegetables eaten per-day as predicted by demographic factors, but also examined the effects of environmental context on portion size and food groups that are eaten together. This is important because child healthy eating is complex and multifaceted and by taking this approach, we can observe another viewpoint of what vegetables children are habitually eating and when.

As a large amount of data was available using the UK NDNS, the statistical models were built on one set of data and then tested on another sample of participants. This reduces the exploratory nature of the research and allows confirmation of models rather than a single exploratory analysis. In particular, this is useful because the EO analyses for vegetable portion sizes initially showed that some food group weights (e.g. the weight (g) of carbohydrates, dairy and fruit in the EO) were found to add to the model, but this was not confirmed in the test dataset. This means that there is either a small or no effect of amounts of other foods groups eaten on vegetable portion sizes eaten. Nonetheless, in the logit models, it shows that these food groups do matter for whether any vegetables are eaten or not.

4.2. Limitations

The limitations of using food diaries and estimated intake have been noted extensively elsewhere [54]. Estimates of energy intake may be both under and over-estimated. However, the current study attempts to limit this problem by examining counts of vegetables eaten and which food groups were present at EOs. Even if portion size estimates are not accurate, they are supplemented by counts of whole foods and whole food groups. Whilst this mitigates against the limitations of dietary diaries, exploring food groups also introduces its own constraints. Many foods cannot be sorted into groups that are agreed upon. For example, nuts and seeds are sometimes grouped with fruits, and other times with protein [55]. Thus, configurations of food groups could be ambiguous, as some foods within the food group may be better predictors of vegetable intake than others. Furthermore, whilst large-scale diary data is useful for information regarding what children eat (and sometimes how they eat), it is not helpful to answer questions relating to why children are eating particular foods or meals. Research questions regarding choice and palatability of preferred foods cannot be answered and therefore explanations for why children eat certain foods together and in specific contexts are limited.

4.3. Future research

Ethnicity predicted that higher counts of vegetables are eaten per-day by BAME children, which may relate to cultural recipes for meals and ingredients used. The study also shows that there are multiple opportunities to increase vegetable intake throughout the day. When looking to different cultures, traditional breakfasts in Asian countries tend to include rice, noodles or soup in the morning complemented by vegetables [56]. Therefore, future research could investigate increasing vegetable intake outside of home evening meal times by encouraging eating vegetables at breakfast and snack times, as well as in smaller portions throughout the day.

5. Conclusion

This study examined children's vegetable intake using the UK NDNS years 1-9. It was found that daily vegetable intake was predicted by age, ethnicity and variety of vegetables eaten. When vegetables are eaten, they are usually consumed at home, with family members and at evening meals. Portion sizes of vegetables were often smaller than recommended, and vegetables were rarely eaten alone. Vegetable presence within an EO was predicted by other food groups present, such as carbohydrates and proteins, whereas foods high in fats, sugars and salt predicted absence of vegetables. Future research may investigate different contexts and opportunities to eat vegetables, whilst considering other foods available, such as eating vegetables with less "competitive" palatable foods, offering them at breakfast and as snacks.

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Conflict of Interest

None.

Authorship

Conceptualization and study design, L.R.C., P.B-B. and M.M.H.; Data curation, L.R.C.; Formal analysis, L.R.C.; Writing-Original draft, L.R.C.; Writing-Review and editing, L.R.C., P.B-B. And M.M.H.

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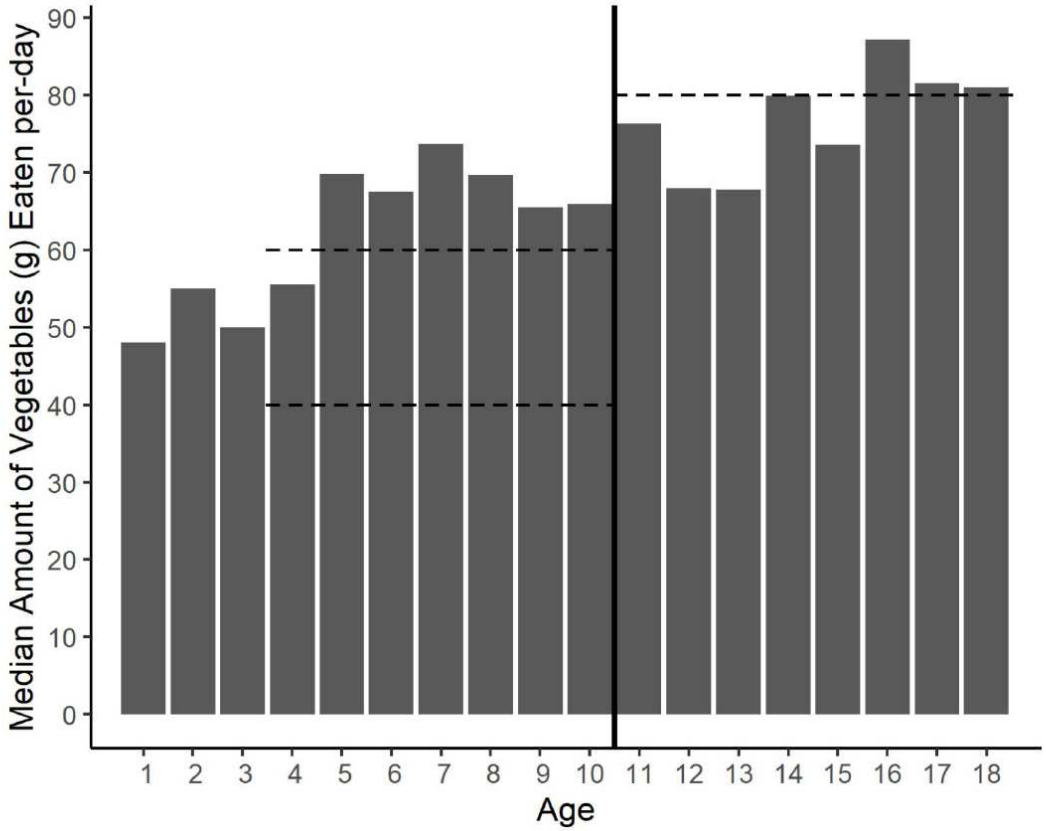

Figure 1. Median amount of vegetables (g) eaten per-day by age group. The vertical centre line divides 4-10 year olds from 11-18 year olds as government recommendations for vegetable portion sizes change from 40-60g (4-10 year olds) to 80 g for 11-18 year olds indicated by the horizontal dashed lines.

Table 1. Participant Characteristics.

Participant Characteristics.	
Total, Male (%)	6547, 3351 (51.18)
Ethnic group, N (%)	
White/White British	5717 (87.32)
Black/Black British	161 (2.46)
Asian/Asian British	374 (5.71)
Mixed ethnic Group	190 (2.90)
Any other group	105 (1.60)
Age Group, N	
1.5-3 years	1172
4-10 years	2554
11-18 years	2821
BMI Category, N (%)	
Normal Weight	4577 (69.91)
Over Weight	871 (13.30)
Obese	1099 (16.78)
Equivalised income	
Mean (SD) [Range]	25952 (18896) [-1.00 – 137195]
Parental Employment Status, N (%)	
Higher managerial and professional occupations	1056 (16.13)
Lower managerial and professional occupations	1618 (24.71)
Intermediate occupations	589 (9.00)
Small employers and own account workers	731 (11.17)
Lower supervisory and technical occupations	591 (9.03)
Semi-routine occupations	916 (13.99)
Routine occupations	714 (10.91)
Never worked	229 (3.50)
Other	104 (1.59)

Table 2. Top ten most consumed cooked and raw vegetables over four-day food diaries and their absolute counts for number of times eaten.

Cooked Vegetables	Absolute Count	Raw Vegetables	Absolute Count
Onions	5678	Cucumber raw	3379
Carrots	5254	Tomatoes raw	2656
Beans	4682	Garlic raw	2446
Peas	3288	Lettuce raw	2156
Tomatoes	2983	Peppers raw	1450
Sweetcorn	2605	Carrot raw	1161
Broccoli	2302	Onions raw	795
Peppers	1953	Ginger root-raw	555
Mushrooms	1312	Coleslaw	352
Mixed Vegetables	789	Mixed leaf salad	284

Table 3. Parameters for linear models predicting average daily absolute counts of vegetables and average daily intake (g) of vegetables consumed.

	Average Daily Absolute Vegetable Count			Average Daily Vegetable Intake (g)		
Predictor/Factor	Estimates	std. Error	p-value	Estimates	std. Error	p-value
(Intercept)	-0.17	0.04	<0.001	-3.47	5.75	NS
Age	-0.01	0.00	<0.001	1.89	0.72	0.008
Age^2				0.01	0.04	NS
Ethnicity	(Reference category White or White British)					
Asian or Asian British	0.87	0.05	<0.001	-14.48	3.05	<0.001
Mixed Ethnic Group	0.17	0.07	0.023	-14.97	4.11	<0.001
Black or Black British	0.45	0.08	<0.001	-3.79	4.41	NS
Any other Group	0.36	0.10	<0.001	-5.43	5.52	NS
BMI Category	(Reference category Normal-Weight)					
Over-Weight	-0.01	0.04	NS	-0.09	2.48	NS
Obese	-0.03	0.04	NS	1.21	2.23	NS
Equivalized Income	0.00	0.00	NS	0.00	0.00	0.001
Parental Employment Status	(Reference category Higher managerial and professional occupations)					
Lower managerial and professional occupations	-0.05	0.05	NS	-2.65	2.56	NS
Intermediate occupations	-0.14	0.06	0.019	-2.58	3.47	NS
Small employers and own account workers	-0.14	0.06	0.011	4.23	3.21	NS
Lower supervisory and technical occupations	-0.10	0.06	NS	0.63	3.53	NS
Semi-routine occupations	-0.16	0.06	0.006	2.51	3.27	NS
Routine occupations	-0.08	0.06	NS	-3.21	3.46	NS
Never worked	-0.09	0.09	NS	1.87	5.02	NS
Other	-0.07	0.12	NS	-2.44	6.75	NS
Vegetarian or Vegan	(Reference category Neither)					
Vegetarian	0.31	0.11	0.005	35.31	6.11	<0.001

Vegan	1.37	0.49	0.006	79.04	27.77	0.004
Vegetable Variety Index	0.41	0.00	<0.001	2.39	0.46	<0.001
Total Vegetable Count				5.03	0.25	<0.001
Average Daily Energy Intake				0.02	0.00	<0.001
Observations	3228			3228		
R^2 / R^2 adjusted	0.811 / 0.810			0.549 / 0.546		
F- Statistic, p-value	F(19, 3208) = 726.7, p<0.001			F(22, 3205) = 177.5, p<0.001		

Table 4. Total number of absolute counts and total eating occasions (and percentage of the total) that vegetables were consumed by location, who the child was eating with and time of day.

	Absolute count of Vegetables Eaten (%)		**Number of Eating Occasions including Vegetables (%)**		**Total Number of Eating Occasions (%)**	
Location						
Home	42343	(77.00%)	17869	(71.31%)	85104	(68.39%)
Leisure	283	(0.51%)	173	(0.69%)	1947	(1.56%)
Food Outlet	1714	(3.12%)	888	(3.54%)	3349	(2.69%)
On the Go	690	(1.25%)	371	(1.48%)	6014	(4.83%)
School/Workplace	6283	(11.43%)	3959	(15.80%)	18394	(14.78%)
Other	3676	(6.68%)	1799	(7.20%)	9628	(7.74%)
Who with						
Alone	2679	(4.87%)	1291	(5.15%)	15220	(12.23%)
Parents only	11542	(20.99%)	5043	(20.12%)	25449	(20.45%)
Children only	2346	(4.27%)	1133	(4.52%)	7950	(6.39%)
Friends only	6207	(11.29%)	3767	(15.03%)	19827	(15.93%)
Multiple groups – Family and Friends	28066	(51.04%)	11690	(46.65%)	41188	(33.10%)
Other	4149	(7.55%)	2135	(8.52%)	14802	(11.90%)
Time of Day						
6am to 8:59am	367	(0.66%)	279	(1.11%)	17500	(14.06%)
9am to 11:59am	1847	(3.36%)	1223	(4.88%)	20794	(16.71%)
12 noon to 1:59pm	12451	(22.64%)	6752	(26.94%)	23753	(19.09%)
2pm to 4:59pm	6743	(12.26%)	3132	(12.50%)	21049	(16.92%)
5pm to 7:59pm	29597	(53.82%)	12198	(48.68%)	29173	(23.44%)
8pm to 9:59pm	3675	(6.68%)	1359	(5.42%)	10030	(8.06%)
10pm to 5:59am	309	(0.56%)	116	(0.46%)	2137	(1.72%)
Total Counts	**54989**		**25059**		**124436**	

Table 5. Results of analysis of variance by Satterthwaite's method, and parameters from multilevel modelling for portion sizes of Vegetables.

		Portion size of Vegetables (g) in EO				
Predictor/Factor	F-Test, p-value	Estimates	std. Error	CI	t- Statistic	p-value
(Intercept)		40.66	7.30	26.35 – 54.97	5.57	<0.001
Age	F(1, 5202) = 11.70, p<0.001	2.43	1.41	-0.33 – 5.19	1.72	NS
Week Day	(Reference category Mon-Fri) F(1, 12327) = 9.31, p=0.002					
Weekend		4.36	1.43	1.56 – 7.16	3.05	0.002
Location	(Reference category Home) F(5, 12243) = 28.40, p<0.001					
Place of leisure		-41.43	8.53	-58.14 – -24.72	-4.86	<0.001
Food Outlet		-24.50	3.50	-31.36 – -17.63	-6.99	<0.001
On the Go		-37.55	5.25	-47.85 – -27.26	-7.15	<0.001
At School/Work		-23.54	3.09	-29.59 – -17.48	-7.62	<0.001
Other		-3.00	2.63	-8.15 – 2.15	-1.14	NS
Who with	(Reference category Alone) F(5, 12192) = 4.94, p<0.001					

Parents Only		7.10	4.46	-1.65 – 15.85	1.59	NS
Children Only		6.93	4.89	-2.64 – 16.51	1.42	NS
Friends Only		-7.10	5.04	-16.99 – 2.78	-1.41	NS
Multiple Groups- Family and Friends		6.33	4.27	-2.05 – 14.70	1.48	NS
Other		1.27	4.85	-8.23 – 10.77	0.26	NS
Time of Day	(Reference category 6am to 8:59am) F(6, 12315) = 5.77, p< 0.001					
9am to 11:59am		15.36	6.33	2.96 – 27.77	2.43	0.02
12 noon to 1:59pm		11.07	5.92	-0.52 – 22.67	1.87	NS
2pm to 4:59pm		11.22	5.96	-0.46 – 22.91	1.88	NS
5pm to 7:59pm		18.05	5.81	6.66 – 29.43	3.11	0.002
8pm to 9:59pm		9.21	6.38	-3.31 – 21.72	1.44	NS
10pm to 5:59am		-10.24	14.29	-38.26 – 17.77	-0.72	NS
Day Energy intake (kcal)	F(1, 9351) = 53.71, p< 0.001	0.01	0.00	0.01 – 0.01	7.33	< 0.001
Vegetarian Or Vegan	(Reference category Neither) F(2, 2945) = 5.38, p= 0.005					

Vegetarian		21.19	6.56	8.32 – 34.05	3.23	0.001
Vegan		28.34	48.05	-65.83 – 122.51	0.59	NS
Vegetable Variety (count eaten)	F(1, 2425) = 68.99, p< 0.001	1.95	0.24	1.49 – 2.41	8.31	< 0.001
Weight (g) of Carbohydrates in EO	F(1, 12356) = 2.62, NS	0.01	0.01	-0.00 – 0.03	1.62	NS
Weight (g) Dairy in EO	F(1, 12174) = 0.00, NS	0.00	0.02	-0.04 – 0.04	0.02	NS
Weight (g) Fruit in EO	F(1, 12324) = 6.06, p= 0.01	-0.04	0.02	-0.08 – -0.01	-2.46	0.01
Age x Location	F(5, 12269) = 5.74, p< 0.001					
Age-Leisure		-3.16	1.56	-6.21 – -0.11	-2.03	0.04
Age-Food Outlet		-1.01	0.64	-2.26 – 0.23	-1.60	NS
Age-On the Go		-2.98	1.02	-4.98 – -0.98	-2.91	0.004
Age-School		-2.68	0.56	-3.78 – -1.57	-4.76	< 0.001
Age-Other		-0.76	0.53	-1.80 – 0.29	-1.42	NS
Age x Who with	F(5, 12171) = 2.09, NS					
Age-Parents Only		-0.40	0.72	-1.81 – 1.02	-0.55	NS

Age-Children Only		-0.66	0.87	-2.37 – 1.05	-0.75	NS
Age-Friends Only		-1.82	0.83	-3.44 – -0.20	-2.20	0.03
Age-Multiple Groups- Family and Friends		-0.26	0.69	-1.62 – 1.09	-0.38	NS
Age-Other		-1.31	0.80	-2.88 – 0.26	-1.64	NS
Age x Time of Day	F(6, 12311) = 3.69, p= 0.001					
Age-9am to 11:59am		3.48	1.36	0.82 – 6.13	2.57	0.01
Age-12 noon to 1:59pm		1.65	1.29	-0.88 – 4.18	1.28	NS
Age-2pm to 4:59pm		1.63	1.30	-0.92 – 4.18	1.25	NS
Age-5pm to 7:59pm		2.59	1.27	0.09 – 5.08	2.03	0.04
Age-8pm to 9:59pm		2.24	1.36	-0.43 – 4.92	1.65	NS
Age-10pm to 5:59am		2.88	2.33	-1.68 – 7.44	1.24	NS
Age x Vegetarian or Vegan	F(1, 2284) = 0.86, NS					
Age-Vegetarian		1.03	1.11	-1.14 – 3.20	0.93	NS
Age x Weight (g) Fruit in EO	F(1, 12344) = 1.30, NS	-0.00	0.00	-0.01 – 0.00	-1.14	NS

Random Effects	
σ^2	3887.61
$\tau_{00\ participants}$	863.78
ICC	0.18
$N_{\ participants}$	3071
Observations	12385
Marginal R^2 / Conditional R^2	0.154 / 0.308

EO = Eating Occasion.

Table 6. Results of analysis of deviance with Type II Wald chi-square tests method, and parameters from multilevel logit modelling for whether vegetables are included in the eating occasion or not.

		Odds of EO Including Vegetables					EO Counts
Predictors	χ^2 – Tests, p-value	Odds Ratios	std. Error	CI	Wald Statistic	p-value	EO Count (with vegetables)
(Intercept)		0.54	0.15	0.40 – 0.72	-4.25	<0.001	
EO Contains Carbohydrates	$\chi^2(1) = 868.31$, p<0.001	0.18	0.15	0.14 – 0.24	-11.49	<0.001	36,310 (10,775)
EO Contains Protein	$\chi^2(1) = 5738.96$, p<0.001	0.82	0.15	0.60 – 1.11	-1.30	NS	20,339 (9,199)
EO Contains Dairy	$\chi^2(1) = 307.82$, p<0.001	0.11	0.18	0.08 – 0.16	-12.07	<0.001	9,049 (2,825)
EO Contains FSS	$\chi^2(1) = 217.67$, p<0.001	0.73	0.04	0.68 – 0.79	-8.28	<0.001	26,942 (3,298)
EO Contains Fruit	$\chi^2(1) = 40.15$, p<0.001	0.04	0.17	0.03 – 0.05	-19.49	<0.001	12,037 (1,871)
EO Contains Carbohydrates and Protein	$\chi^2(1) = 92.82$, p<0.001	12.85	0.16	9.42 – 17.54	16.08	<0.001	17,288 (8,217)
EO Contains Protein and Dairy	$\chi^2(1) = 256.71$, p<0.001	16.77	0.21	11.01 – 25.55	13.13	<0.001	3,709 (1,797)
EO Contains Carbohydrates and Fruit	$\chi^2(1) = 101.65$, p<0.001	28.51	0.18	20.06 – 40.52	18.68	<0.001	4,789 (1,582)
EO Contains Carbohydrates and Dairy but not Protein	$\chi^2(2) = 394.93$, p<0.001	36.76	0.19	25.51 – 52.99	19.33	<0.001	3,033 (935)

EO Contains Carbohydrates, Dairy and Protein		0.56	0.13	0.44 – 0.72	-4.61	< 0.001	3,287 (1,612)
EO Contains FSS but not Carbohydrates or Protein	χ^2 (3) = 468.02, p< 0.001	0.03	0.17	0.02 – 0.04	-21.39	< 0.001	15,642 (188)
EO Contains FSS and Carbohydrates but not Protein		0.99	0.06	0.87 – 1.12	-0.16	NS	5,387 (659)
EO Contains FSS and Protein but not Carbohydrates		1.04	0.10	0.85 – 1.27	0.37	NS	860 (257)
EO Contains Protein and Fruit but not Carbohydrates	χ^2 (2) = 253.93, p< 0.001	24.85	0.21	16.58 – 37.24	15.57	< 0.001	424 (150)
EO Contains Protein, Fruit and Carbohydrates		0.76	0.08	0.65 – 0.89	-3.41	< 0.001	2,484 (1,149)

Random Effects	
σ^2	3.29
$\tau_{00\ participant}$	0.50
ICC	0.13
$N_{\ participant}$	3256

Observations	61749
Marginal R^2 / Conditional R^2	0.509 / 0.573

EO = Eating Occasion, EO Count = Total number of eating occasions with this combination and with vegetables. FSS = Foods high in fats, sugar and salt (e.g. puddings, pastries, sweets, biscuits, crisps, savoury items and chocolate).