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Citation:

Evans, C and Hutchinson, J and Christian, MS and Hancock, N and Cade, JE (2018) Measures of low food variety and poor dietary quality in a cross-sectional study of London school children. Eur J Clin Nutr. ISSN 1476-5640 DOI: <https://doi.org/10.1038/s41430-017-0070-1>

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**Measures of low food variety and poor dietary quality in a cross-sectional study of
London school children**

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Running title: Food variety and diet quality in children

Keywords: food variety, children, diet quality, nutrient adequacy, dietary assessment, cross-sectional survey, nutritional epidemiology

Word count of abstract: 238

Word count of main body: 3677

Conflict of interest:

This project was funded by the National Institute for Health Research Public Health Research (NIHR PHR) programme (project number 09/3001/19). Visit the PHR programme website for more information. The views and opinions expressed therein are those of the authors and do not necessarily reflect those of the PHR programme, NIHR, NHS or the Department of Health. Further analysis was commissioned by the charity Kids Company®, UK (now disbanded). CELE, JH, NH, MSC and JEC had financial support from the UK based charity, Kids Company®, for the submitted work. Kids Company® had no role in the design, analysis or writing of this article. CELE, JH, NH, MSC and JEC have no other relationships with companies that might have an interest in the submitted work.

Abbreviations:

BMI – Body Mass Index

NDNS – National Diet and Nutrition Survey

RNI – Reference Nutrient Intake

EAR – Estimated Average Requirement

1 **Abstract**

2 **Background/objectives:** Simple screening tools to measure nutritional adequacy in a public
3 health context in developed countries are currently lacking. We explore the relationship
4 between food variety and nutrient intake of London school children using a simple tool with
5 potential use for screening for inadequate diets.

6 **Subjects/methods:** A cross-sectional survey was carried out in 2010. The survey included
7 2579 children aged 7-10 years in 52 primary schools in East London in the UK. The analysis
8 included 2392 children (93% of the original sample). Food variety was assessed as the total
9 number of listed foods recorded over 24 hours using the validated Child and Diet Assessment
10 Tool (CADET) comprising 115 listed foods divided into 16 food categories. Dietary quality
11 was determined by the proportion of children meeting recommended intakes of individual
12 micronutrients, namely; calcium, iron, zinc, folate, vitamin A and vitamin C.

13 **Results:** The mean number of CADET listed foods consumed daily by children was 17.1
14 (95%CI 16.8, 17.5). Children who consumed fewer than 11 foods on the collection day had
15 particularly low nutrient intakes. Children consuming 3 different vegetables and 2 different
16 fruits on average consumed 19-20 listed foods. It was estimated between 4 and 20% of
17 children did not meet the recommended levels for individual micronutrients during the period
18 of data collection.

19 **Conclusions:** A simple method using food counts to assess daily food variety may help public
20 health nutritionists identify groups of children at risk of inadequate diets.

21 **Introduction**

22 A high quality diet recommended by the World Health Organisation (WHO) contains more
23 fruits and vegetables and lower trans fats and free sugars, and is associated with reduced risk
24 of common non-communicable diseases such as type 2 diabetes^{1, 2}. Developing good dietary
25 habits in childhood is important since these can track into adulthood³. However, many
26 children and adolescents in developed countries have poor quality diets and high levels of
27 obesity⁴; and children from low income households tend to have worse diets⁵ with lower
28 intakes of many vitamins and minerals⁶, higher likelihood of missing meals⁷ and higher rates
29 of obesity⁸⁻¹⁰.

30 Quality assessments of the whole diet can be difficult, particularly in children. There is no
31 universally agreed definition of diet quality, although the term is often used in relation to
32 meeting dietary recommendations of optimum levels of foods and/or nutrients such as the
33 Healthy Eating Index (HEI)¹¹. Nutrient scoring involves analysis using dietary software¹²⁻¹⁵
34 but simpler methods that provide a score without the need for software are potentially more
35 useful as quick screening tools. A simple tick list that collects food variety data^{14, 16-20} may
36 be an easier and less burdensome method. Very low burden methods or screening tools that
37 simply count food variety in children which could be used to indicate dietary quality in a
38 public health or clinical context are currently lacking. Existing research on UK and US
39 adults have reported the importance of food variety on dietary quality, including nutrient
40 adequacy²¹⁻²³, but there is little research on children.

41 Studies have highlighted the importance of diets rich in calcium,²⁴ iron,²⁵ folic acid²⁶, zinc²⁶
42 and vitamin A²⁶ and the roles these nutrients play in cell division, growth, cognitive
43 development and long term health²⁷⁻²⁹. With the addition of vitamin C, these micronutrients,
44 are also included in the nutrient standards for school meals in England³⁰. We therefore

45 suggest a micronutrient approach to assess dietary quality in children. As a measure of
46 adequacy, we have used Estimated Average Requirements (EAR), the level needed to meet
47 the needs of half the population³¹.

48 Our aims were to explore how a simple count of food variety, with an emphasis on fruit and
49 vegetables, is related to nutrient intake in primary school children, and whether such a tool
50 has potential use for low burden screening for inadequate diets in groups of children. We
51 focussed on intakes of micronutrients previously associated with good health by determining
52 the proportion of children in our study consuming lower than the EAR for calcium, folic acid,
53 iron, zinc, vitamin C and vitamin A based on foods consumed in a single day and standard
54 portion sizes.

55 **Methods**

56 Secondary analysis of cross-sectional data was undertaken using baseline dietary
57 measurements collected from 2579 children (aged 7-10 years) who participated in a
58 randomised controlled trial (RCT) to evaluate the Royal Horticultural Society (RHS) School
59 Gardening Programme (NIHR project number PHR Project 09/3001/19). Dietary data were
60 collected between November 2010 and January 2011 from children attending 52 primary
61 schools in eight deprived and ethnically diverse London boroughs. The trial was powered to
62 see differences in fruit and vegetable consumption of 0.5 portions. Trial registration number
63 ISRCTN11396528, details of this trial are described elsewhere^{32, 33}. Ethical approval was
64 obtained from Leeds Institute of Health Sciences and Leeds Institute of Genetics, Health and
65 Therapeutic joint ethics committee (Reference number: HSLT/09/012 amendment 2). Written
66 informed consent from schools and parents of children taking part was obtained.

67 Dietary intake was assessed prospectively over 24 hours using a modified version of the
68 validated Child And Diet Evaluation Tool (CADET) diary which comprises a tick list of 115

69 food and drink items, divided into 16 food categories^{34, 35} (see supplementary material for
70 categories). The CADET does not require users to estimate portion size but uses age and
71 gender specific food portion sizes based on 7 day weighed intakes collected for the National
72 Diet and Nutrition Survey (NDNS) of young people³⁶ to calculate food and nutrient intake.
73 The CADET diary was split into two: a school diary to record all food consumed at school,
74 and a home diary to record all food consumed at home. Both diaries included the same food
75 items, with different meal/snack time options. Trained fieldworkers filled in the CADET
76 diary during the school day (morning break, lunch, afternoon break), and parents completed
77 the diary for evening and morning food consumption (after school/before tea, evening
78 meal/tea, after tea/during night, and breakfast/before school)^{35, 37} Each listed food consumed,
79 was ticked under the appropriate meal time. Fruit salad, for example, is a separate listed food
80 and would add a count of one to the food variety score. A DVD explaining how to complete
81 the CADET diary was sent home for parents/carers and children to watch
82 <https://www.youtube.com/watch?v=A1bzqaJiHq0>. If sections of the diaries were not
83 completed or children forgot to return the home part of the CADET, a fieldworker asked the
84 children to report this information during an interview on the following day to minimise
85 missing data and reduce bias. Different fruits, vegetables and meats are counted as separate
86 foods, whereas carbonated drinks which have a similar nutrient profile contribute one food.
87 Children's intake was analysed in relation to the UK EAR intake of micronutrients for 7-10
88 year old children³¹, and to updated EARs for energy, total fat and total carbohydrates for 8
89 year old boys and girls³⁸, the mean age of the children. EARs for maximum recommendations
90 of total fat and carbohydrates were calculated based on 35% and 50% respectively of the
91 energy EARs for 8 year olds, and energy was assessed in relation to +/-20% of the EARs for
92 the average 8 year old.

93 Children were excluded if they did not complete a food diary for the whole day, that is, they
94 had a missing home or school section, or they had extremely high energy intakes of more
95 than 5410Kcal or high fruit and vegetable intakes of more than 999g. The mean number of
96 CADET listed foods consumed for children meeting, and not meeting, the recommended
97 intakes of a number of micronutrients were calculated. Similarly the mean number of listed
98 foods consumed by children missing meals, and those not missing meals was calculated. The
99 mean number of listed foods consumed by quintile of energy intake was also produced. A
100 food variety score was generated ,using the total number of different listed foods consumed.
101 Children were then split into one of seven ‘food variety’ groups according to the number of
102 listed foods consumed in the 24 hour period: 4-10, 11-12, 13-14, 15-16, 17-18, 19-20, 21+
103 foods (no children consumed less than four food types). These groupings allowed for a
104 roughly equal distribution of children. Graphs were produced indicating the percentage of
105 children meeting recommended amounts for the six micronutrients and energy for each of the
106 seven food variety groups. The graphs were repeated for those who ate sweet and/or savoury
107 snacks and for those who did not; to check whether excluding energy dense foods had an
108 effect on the results (see supplementary materials). Additionally, the mean number of listed
109 foods consumed in each of the 16 food categories (e.g. drinks, fruit as shown in table 3), was
110 calculated for different food variety groups to determine recommendations for an optimal diet
111 in terms of dietary quality. To determine whether social deprivation was associated with not
112 meeting the EARs, the mean Index of Multiple Deprivation (IMD) for those meeting the
113 EAR for each nutrient was compared to the mean for those not meeting the EARs using two-
114 sided t-tests. The post code for a child’s home was used to determine IMD (which ranged
115 from 2 to 70 in this dataset), if this was not available the post code for the school was used.
116 Analyses were performed using Stata version 13; the confidence intervals or standard errors
117 of means and proportions took into account the clustering of children within schools. P
118 values of lower than 0.05 were taken as significant.

119 **Results**

120 Out of 2579 children recruited into the trial at baseline who provided consent, 2461 children
121 returned completed food diaries. After excluding 69 children who did not complete one or
122 both of the sections (home and school) of their food diary; thirty nine children were excluded
123 due to very high energy intakes and 30 children were excluded due to very high fruit and
124 vegetable intakes. The final sample size was 2392, 93% of the original sample. The mean age
125 of the children was 8.3 years (SD 0.7) (1188 girls and 1204 boys). Twenty-eight percent of
126 the children received free school meals and 33% of the sample ate a packed lunch. English
127 was spoken as an additional language by 47% of the sample. Education was reported by 60%
128 of the families, and of those, 39% had a member of the family educated to degree level or
129 higher. Postcode information was provided by 878 families (37%) used to determine IMD
130 score (Table 1); with school postcode used for the remaining pupils.

131 **Nutrient intake adequacy**

132 The majority of children met the recommended intakes of the important micronutrients on the
133 single collection day (see table 1). However, 18.0% did not meet the EAR for zinc, 18.4% for
134 vitamin A, 11.0% for iron, 9.5% for calcium, 7.1% for folic acid, and 3.8% did not meet the
135 micronutrient intake for vitamin C. For energy, 40.3% of boys and 28.6% of girls had intakes
136 below the gender specific EARs, boys being 68% more likely have intakes below their EAR
137 for energy than girls. Boys were 31% to 51% less likely to meet the EARs for the specified
138 micronutrients than girls, and differences were statistically significant for energy, zinc, folate,
139 iron, vitamin A, but not calcium or vitamin C. There were no associations between higher
140 IMD score, i.e. higher deprivation, and not meeting EARs, except for folic acid where
141 children who did not meet recommendations on the day were more likely to be from more
142 deprived areas (IMD score (95%CI= 36.3 (34.3, 38.3) compared to 32.8 (32.2, 33.4)
143 (p=0.002)).

144 **Food Variety**

145 In the total sample, the mean number of different CADET listed foods consumed over the day
146 was 17.1 (95% CI 16.8, 17.5) out of 115 listed in the diary. The increase in mean nutrient
147 intake by the increase in numbers of listed foods (food variety) consumed per day is detailed
148 in table 2. Figure 1 shows how the percentage of children meeting EARs for individual
149 micronutrients varies food variety group. The proportion of children meeting individual
150 micronutrient requirements is higher as the number of listed foods consumed increases; once
151 19-20 food items/day are consumed 90% or more children met the EARs for all the
152 micronutrients of interest. For the 4-10 food items/day group the percentage of children
153 meeting nutrient requirements is particularly low. In this sample, 136 children (5.7%)
154 reported that they consumed 10 foods or fewer on the day of recording. In relation to energy
155 EARs, children were more likely to exceed + 20% energy EARs if they consumed over 14
156 different foods; similar distributions were observed for those who consumed no snacks and
157 confectionery (N=130) (see supplementary data Figure 1), and for those who did consume
158 snacks and confectionery (N=2082) (see supplementary data Figure 2).

159 As food variety increased, the number of listed foods consumed in all 16 categories increased
160 (see table 3). Higher food variety occurs as children eat more of all types of foods, but
161 particularly for vegetables and fruit. Children who consumed a total of 19-20 listed foods, on
162 average typically consumed three different types of vegetables and two different types of
163 fruit. On average drinks, pizza, pasta, rice, snacks and breakfast cereal provided the most
164 variety for children who only consumed a total of 4-10 listed foods.

165 Missing meals had an impact on food variety. Out of 2392 children, 3.5 % (84) missed any
166 meal, 2.0% (49) missed breakfast, 0.3% (7) missed lunch, 1.6% (37) missed the evening meal
167 and 0.4% (9) missed more than one meal. The mean number of listed foods consumed by

168 children who missed a meal was 12.4 (95%CI 11.4, 13.5) compared with 17.3 (95%CI 16.9,
169 17.7) for those not missing a meal. Food variety was also lower for those children consuming
170 diets lower in energy. The mean number of listed foods consumed by quintile of energy
171 intake was 12.5 (95%CI 12.1, 12.9) in the lowest quintile, 14.8 (95%CI 14.5, 15.1) for Q2,
172 16.7 (95%CI 16.3, 17.1) for Q3, 18.5 (95%CI 18.2, 18.9) for Q4 and 23.1 (95%CI 22.5, 23.7)
173 for the highest quintile.

174 **Discussion**

175 We aimed to explore the relationship between food variety and nutrient intake of London
176 school children using a low burden simple tool with potential use for screening for inadequate
177 diets. Food variety was determined using a food-based count from a food tick list tool
178 (CADET), requiring no scoring from nutrient estimates. The analyses did not classify
179 individual children in the study, but indicated group mean nutrient intakes. On average in this
180 single day assessment, about 19 or more different listed foods or drinks (out of a possible 115
181 listed on the CADET tool) needed to be consumed for an optimal diet in terms of selected
182 micronutrients and our results indicate this would also typically include three different types
183 of vegetables and two types of fruit. As food variety increased, mean energy intake also
184 increased. If 19 or more food items were consumed, 90% of children had energy intakes
185 above the recommended levels which has implications for weight gain. Lower food variety
186 on a single day was associated with risk of not meeting recommended amounts of nutrients,
187 particularly zinc and vitamin A. If the number of food items was below ten foods, children
188 were at extremely high risk of not meeting any of the studied micronutrient requirements on
189 the day. Children who missed a meal or had low energy intakes had less variety in their diets
190 and consequently lower quality diets in terms of nutrients.

191 There is little research on food variety in developed countries, other than in adults²¹⁻²³. In UK
192 adults, higher food variety scores were associated with both increased nutrient adequacy and

193 reduced all-cause mortality; this used a simple count of foods consumed at least once a week
194 from a 127-item FFQ with a large proportion of listed fruit and vegetables^{22 23}. In the British
195 NDNS rolling programme⁴, micronutrient deficiencies were highlighted in some children and
196 adolescents particularly vitamin A (6% children, 13% adolescents) and iron intakes (1%
197 children, 26% adolescents). Children at high risk of poor quality diets may be going
198 unnoticed because they consume sufficient or too much energy but insufficient levels of
199 micronutrients; many measures to assess dietary adequacy in children are based on measures
200 of body fatness³⁹. A simple food variety measure may be needed to identify groups at risk of
201 poor nutrient intake that focuses on meat, fruits, vegetables, pulses and wholegrain; the main
202 food sources of important micro-nutrients. There is evidence that children from the most
203 socially deprived areas are more likely to have poor quality diets eating high energy dense
204 food, and to be overweight or obese^{40, 41}. This may be due to food insecurity or food
205 insufficiency where there is a lack of access to sufficient quantity of affordable nutritious
206 food for economic or other reasons respectively⁴²⁻⁴⁴. Surprisingly, we found little evidence of
207 associations between IMD and meeting nutrient intake recommendations, except for folic
208 acid. However, the proportion of children having a free school meal (28%) in this study was
209 much higher than the average for England (17%) which may have attenuated any existing
210 association with deprivation.

211 Traditionally, screening tools for food security or food insufficiency do not consider food and
212 associated nutrient intakes^{18, 35, 45}, although missing meals is usually incorporated which is an
213 important risk factor for poor quality diet^{43, 46}. Results from the National Health and Nutrition
214 Examination Survey (NHANES) report that around 8% of American children are food
215 insufficient⁴⁷ with low serum micronutrient levels⁴⁶. This is similar to the 6% of children we
216 identified as being at particularly high risk of an inadequate diet due to consumption of ten

217 foods or fewer per day; however this percentage may reduce if more days of intake were
218 collected as food intake usually varies by day, resulting in regression to the mean.

219 There were a number of strengths of this study. This is the first to explore methods of
220 assessment to predict the risk of an inadequate diet in children in developed countries based
221 solely on a simple count of food variety. The CADET diary was designed to focus on fruits
222 and vegetables so is weighted towards healthy foods in terms of variety score. This means
223 higher scores are more likely to be achieved through consumption of a variety of fruit and
224 vegetables (13 and 22 food items respectively were listed on CADET for these - see
225 supplementary materials) than through consumption of sugar sweetened drinks, puddings,
226 confectionery and snacks which accounted for a smaller number of listed foods (1, 6, 2, 8
227 respectively on CADET). The similar results obtained when sweet and savoury snacks were
228 excluded supports this interpretation. This increases the likelihood that a high score was
229 based on a higher number of healthy foods. This emphasis on fruit and vegetables is similar
230 to the FFQ used to score food variety in UK adults which was associated with both nutrient
231 adequacy and reduced all-cause mortality²². In our study, a large sample of detailed dietary
232 data was obtained using a validated tool collected by trained fieldworkers in children from
233 diverse backgrounds and analysis took into account clustering within schools. Dietary intake
234 was similar to typical diets of children of this age group in many high income countries and,
235 based on eligibility for free school meals, was representative of the region.

236 There were notable limitations. The sample of children was not necessarily representative of
237 other regions of the UK. There is no universally agreed definition of a low quality diet
238 although our definition based on important micro-nutrients is one possible approach¹¹. Our
239 data only covers one 24 hour period, and is not representative of individual usual intake. The
240 average number of foods and nutrients consumed over a week would be closer to the mean
241 and fewer children would be in the lowest food variety band. Intake of foods was estimated

242 using an average portion size from weighed records in the UK NDNS according to age and
243 gender³⁴ rather than asking children to state their portion size. However, children who
244 consume a very low variety of foods may consume larger portion sizes than average for the
245 foods they do consume, and vice versa for those consuming a high variety of food.
246 Therefore, it is possible we overestimated intake for some children, particularly those having
247 the most varied diets and underestimated intake of those with low food variety. It is possible
248 that the number of children who actually missed a meal is less than reported if a parent forgot
249 to fill in part of the diary although steps were taken to minimise missing data. Additionally,
250 socially desirable answers may have been given by parents in the home diary; they may have
251 been more willing to report healthy food than unhealthy foods, with snack foods and
252 beverages more likely to be under-reported. Lastly, we did not collect any information on
253 body mass index (BMI) or measures of food insecurity which meant we could not identify
254 children who were underweight. To avoid the food variety score just reflecting unhealthy
255 foods, energy dense foods such as savoury and sweet snacks could be excluded, although
256 they are currently low in number and excluding them from the count had little effect. In
257 addition, more work is needed to determine how the number of CADET foods consumed
258 changes if intakes are assessed over a period of days, which would be necessary to assess
259 diets of individuals,. This should include validation against weighed dietary records and
260 health outcomes⁴⁸.

261 In summary, a simple count of food variety may be useful to identify groups of children
262 consuming less than optimal diets. A simple tick list questionnaire could be included, as part
263 of a regular health check at school or in the community. This would avoid the need for
264 specialised nutritional analysis software and interpretation. However, more research into the
265 sensitivity and specificity of this suggested approach is warranted, particularly relating to the
266 optimum number of dietary days needed and the need for specific portion sizes.

267

268 Acknowledgements

269 The authors acknowledge Claire McLoughlin and Camilla Nykjaer for their central
270 involvement in collecting the data for this project.

271 Author contributions

272 CELE designed the research protocol and the original statistical analysis plan, secured the
273 additional funding for the additional analysis, wrote the first manuscript and contributed to all
274 versions of the manuscript. JH designed and carried out the analysis, wrote a report and
275 contributed to all versions of the manuscript. JEC contributed to all versions of the
276 manuscript. NH managed the database, made available all data in the analysis and contributed
277 to the final version of the manuscript. MSC managed the data collection of the NIHR project
278 and contributed to the final version of the manuscript.

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Figure Legends

Figure 1: Percentage of London school children aged 7-10 years meeting EAR nutrient requirements by number of CADET listed foods consumed in a day