

Tracking of dietary intakes in early childhood: the Melbourne InFANT Program

Sandrine Lioret, Sarah Mcnaughton, Alison Spence, David Crawford, Karen
Campbell

► **To cite this version:**

Sandrine Lioret, Sarah Mcnaughton, Alison Spence, David Crawford, Karen Campbell. Tracking of dietary intakes in early childhood: the Melbourne InFANT Program. *European Journal of Clinical Nutrition*, Nature Publishing Group, 2013, 67 (3), pp.275-81. <10.1038/ejcn.2012.218>. <inserm-01124412>

HAL Id: inserm-01124412

<http://www.hal.inserm.fr/inserm-01124412>

Submitted on 6 Mar 2015

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

1 **Title:** Tracking of dietary intakes in early childhood: The Melbourne InFANT Program¹.

2

3 **Running head title:** Dietary intakes in early childhood.

4 **Key words:** Food intake; Nutrient intake; Infant; Toddler; Tracking.

5

6 ¹ This study was funded by an Australian National Health and Medical Research Council Project
7 Grant (number 425801).

8

9 **Contributors:** Dr Sandrine Lioret², Dr Sarah A. McNaughton², Dr Alison C Spence², Prof David
10 Crawford², Dr Karen J Campbell²

11

12 ²**Affiliations:** Centre for Physical Activity and Nutrition Research; School of Exercise and Nutrition
13 Sciences; Deakin University; 221 Burwood Hwy, Burwood Victoria 3125, Australia.

14

15 **Corresponding Author:** Sandrine Lioret

16 Centre for Physical Activity and Nutrition Research, C-PAN; School of Exercise and Nutrition
17 Sciences; Deakin University

18 221 Burwood Hwy, Burwood Victoria 3125, Australia

19 Phone: +61 3 9251 7236; Fax: +61 3 9244 6017

20 Email: sandrine.lioretsuteau@deakin.edu.au

21

22 **Abbreviations:** EER, Estimated Energy Requirement; AI, Adequate Intake; EAR, Estimated
23 Average Requirement; IQR, Inter-quartile Range; OR, Odd-Ratio.

1 **Abstract**

2 Background/Objectives: The objectives of the present study were to describe food and nutrient
3 intakes in children aged 9 and 18 months; and to assess tracking of intakes between these two ages.

4 Subjects/Methods: Participants were 177 children of first-time mothers from the control arm of the
5 Melbourne Infant Feeding Activity and Nutrition Trial (InFANT) Program. Dietary intake was
6 collected at 9 and 18 months using three 24-hour diet recalls. Tracking was assessed for food and
7 nutrient intakes using logistic regression analysis and estimating partial correlation coefficients,
8 respectively.

9 Results: While overall nutrient intakes estimated in this study did not indicate a particular risk of
10 nutrient deficiency, our findings suggest that consumption of energy-dense, nutrient-poor foods
11 occurred as early as 9 months of age, with some of these foods tracking highly over the weaning
12 period. Intakes of healthier foods such as fruits, vegetables, dairy products, eggs, fish and water
13 were also relatively stable over this transition from infancy to toddlerhood, along with moderate
14 tracking for riboflavin, iodine, fibre, calcium, and iron. Tracking was low but close to $\rho=0.3$ for
15 zinc, magnesium, and potassium intakes.

16 Conclusions: The tracking of energy-dense, nutrient-poor foods has important implications for
17 public health given the development of early eating behaviours is likely to be modifiable. At this
18 stage of life, dietary intakes are largely influenced by the foods parents provide, parental feeding
19 practices and modelling. This study supports the importance of promoting healthy dietary
20 trajectories from infancy.

21

22

23

24 **Introduction**

25 Early childhood is a vulnerable time with regard to nutrition. This is a period of relatively rapid
26 growth, associated with changing physiological requirements and nutritional needs. This is also a
27 time of dietary transition, from exclusive breast or formula milk consumption to a familial
28 diversified diet. Children's early exposure to foods influences the development of taste and food
29 preferences, which in turn impact on subsequent eating habits^(1,2). Further, some aspects of diet and
30 growth in infancy, such as breast-feeding, protein intake and rapid early weight gain, have been
31 shown to exert an influence on adiposity⁽³⁻⁶⁾ and poor cardiovascular health⁽⁷⁾ in later life.

32 However, despite the importance of eating behaviours throughout infancy, international studies
33 describing food and nutrient intakes in infants or toddlers are limited and primarily cross-sectional⁽⁸⁻
34 ¹⁴⁾. In Australia, only four cross-sectional studies performed >7-10 years ago have reported dietary
35 intakes in children aged 9 months⁽¹⁵⁾, 16-24 months⁽¹⁶⁾, 12-36 months⁽¹⁷⁾ and 1-5 y⁽¹⁸⁾; and there are
36 no national dietary surveys of children <2y. Nonetheless, these few studies have raised concern
37 about some characteristics of weaning diets, such as the excessive energy intake in infancy and
38 toddlerhood⁽¹⁹⁾, and also their overall quality. Existing international research suggests that early
39 diets contain relatively high levels of energy-dense, nutrient-poor foods and beverages, while the
40 consumption of fruits and vegetable is less than recommended^(11,13,19). In terms of nutrient intakes,
41 deficiencies have been shown to be unlikely in industrialised countries, with the possible exceptions
42 of iron, zinc and fibre^(12,18,20).

43 While adherence to complementary feeding guidelines has been shown to predict diet at 3 y⁽²¹⁾
44 and diet has been found to track throughout childhood⁽²²⁻²⁴⁾, less is known about tracking of foods
45 and nutrients during infancy⁽²⁵⁾. Tracking refers to the stability of a relative position in rank of
46 behaviour over time, or the predictability of a measurement of a given risk factor early in life for
47 values of the same risk factor later in life⁽²⁶⁾. The aims of the current study were to cross-sectionally
48 describe food and nutrient intakes in children aged 9 and 18 months and to assess tracking of
49 intakes between these two ages. Dietary data were provided from first-time mothers involved in the
50 control arm of the Melbourne Infant Feeding Activity and Nutrition Trial (InFANT) Program.

51

52 **Materials and methods**

53 *Study design and participants*

54 The Melbourne InFANT Program was a cluster randomised controlled trial, involving first-time
55 mothers from when their infants were 4 to 20 months of age⁽²⁷⁾. The transition to motherhood is
56 likely to be a time when mothers may be more likely to seek information on their changing
57 circumstances and may be more able to enact and maintain behavioural changes given their daily

58 routines are being renegotiated as they find a new equilibrium⁽²⁸⁾. The intervention, conducted in
59 2008-2010 within Greater Melbourne (Victoria, Australia) across areas displaying a wide range of
60 socio-economic positions, focused on parenting skills and strategies aimed at promoting the
61 development of healthy behaviours from early infancy. Briefly, a two-stage random sampling
62 design was used to include English-speaking primary caregivers attending first-time parents'
63 groups, a free and universal service provided by Maternal and Child Health nurses. Eighty six
64 percent of eligible parents consented to participate (n=542). We excluded children from non-first-
65 time mothers (n=14); those lost at follow-up (n=48); and those completing less than two dietary
66 recalls at either 9 or 18 months (n=95). Due to field constraints, not all children were aged exactly 9
67 and 18 months at the two measurement times (T2 and T3, respectively). To avoid a possible
68 influence of age on the results, we excluded from all analyses children younger than 7 months or
69 older than 11 months at T2 (n=19); and those younger than 16 months or older than 20 months at
70 T3 (n=16). Outliers for energy and liquid intakes were excluded according to the criterion of mean
71 \pm 3 SD (n=8). As the aim of the current study is the description of the natural history of dietary
72 intake in early childhood (i.e. independent from the intervention), the present analysis is restricted
73 to children in the control group only. This resulted in a sample of 177 children.

74 The Melbourne InFANT Program was approved by the Deakin University Human Research
75 Ethics Committee and the Victorian Government Department of Human Services, Office for
76 Children, Research Coordinating Committee.

77

78 *Measurements*

79 Self-administered questionnaires were utilized to collect demographic (including education level)
80 and socio-economic data at baseline. Education level was defined in three categories: low
81 (secondary school or below), intermediate (trade and certificate qualifications) or high (university
82 degree or higher). Mother's pre-pregnancy weight and height, duration of pregnancy and infant's
83 age when first introduced to solid foods were also reported. Children's height/length and weight
84 without clothes were measured by trained staff at each time point. Height/length was measured to
85 0.1cm using a calibrated measuring mat (Seca 210, Seca Deutschland, Germany) or portable
86 stadiometer (Invicta IPO955, Oadby, Leicester). Weight was measured to 10 grams using calibrated
87 infant digital scales (Tanita 1582,- Tokyo, Japan). The average of two measures was used in
88 analyses.

89 The children's dietary intakes were assessed by trained nutritionists when they were 9 months of
90 age (from December 2008 to June 2009) and 18 months of age (from August 2009 to February
91 2010) by telephone-administered multi-pass 24-hour recall with parents⁽²⁹⁾. Purpose-designed

92 booklets adapted to age including photographs of common portion sizes and examples of measures
93 were provided to parents to aid estimation of food consumption. The booklets included pictures of
94 cups, bowls, drink containers, and spoons. Images were taken with permission from the Food
95 Model Booklet developed for the 2007 Australian Children's Nutrition and Physical Activity
96 Survey (CNPAS). Food items included in the food model book used at 18 months were those
97 considered difficult for parents to quantify, important to the Melbourne InFANT Program
98 hypotheses, and/or frequently consumed by this age group. Knowledge of frequently consumed
99 foods was based on Webb and colleagues' paper reporting diets of 16-24 month-old Australian
100 children in the Childhood Asthma Prevention Study (CAPS)⁽³⁰⁾. The book included primarily
101 vegetables, fruits, cereals, spreads and non-core foods (energy-dense, nutrient poor foods and
102 beverages). Where available, the portion sizes photographed were based on intakes reported in the
103 CAPS, with three pictures of each food item representing the 25th percentile, median, and 75th
104 percentile of reported intake per eating occasion. Where the food item had not been reported in the
105 CAPS, the amounts photographed were based on reported weights of similar food items. At both 9
106 and 18 month data collections, 2 or 3 non-consecutive days of dietary data were collected, including
107 one weekend day (3 days were available for 92% and 97% of the study sample at T2 and T3,
108 respectively). Calls were unscheduled where possible (96% of all calls). Nutrient intakes were
109 evaluated using the 2007 AUSNUT Database (Food Standards Australia New Zealand, 2008).
110 Where brands of foods or beverages consumed were not found in this database, the nutrient
111 composition data was sought from the manufacturing company or the product's nutrition
112 information panel. Where a reported food or drink could not be matched to an item in AUSNUT
113 2007, such as some infant-specific commercial products, a new food item was created in the
114 database utilising the product's nutrient composition. Recipe creation was informed by recipes
115 frequently described by Melbourne InFANT Program participants. Parents indeed provided detailed
116 information on home-made recipes including ingredients and/or proportions, which enabled the
117 classification of mixed dishes. Data were checked for accuracy by a dietician. Breastfeeding was
118 recorded as minutes of time spent breastfeeding and then converted to volume consistent with
119 previous studies⁽³¹⁾.

120

121 *Analyses*

122 Average daily dietary intakes were calculated for each child. Eighteen food groups were defined, as
123 described in Appendix A. For each food group, we assessed the percentage of subjects consuming
124 the food, along with both median and inter-quartile range intakes (expressed in g/d). Intakes were
125 also estimated amongst consumers of each food group only (Supplementary Table). Mean intakes of

126 macro- and micro-nutrients were estimated along with energy density (excluding liquids). The latter
127 was estimated at the individual level, weighting the composition of each food consumed (energy, in
128 kJ) by its effective consumption (g)⁽³²⁾. Differences in food and nutrient intakes between T2 and T3
129 were tested using Wilcoxon signed rank tests and paired t-tests, respectively. Dietary intakes of
130 selected micro-nutrients were compared with the Nutrient Reference Values for Australia and New
131 Zealand⁽³³⁾. For nutrients with an available Estimated Average Requirement (EAR), we assessed the
132 proportion of the sample with intakes less than the EAR, which is an estimate of the proportion of
133 the population with inadequate intakes⁽³⁴⁾. When EAR was not available, we compared the mean
134 intake to the Adequate Intake (AI)⁽³⁴⁾.

135 With regards to the assessment of tracking, as food intakes changed substantially between 9 and
136 18 months of age and the distributions were highly skewed, we considered food intake either as a
137 binomial variable (consuming, yes/no), or in tertiles (when the percentage of subjects consuming
138 was >66.7%). In this case, a new binomial variable was then defined, i.e. high *vs.* intermediate or
139 low levels of consumption (which corresponds to the 3rd tertile *vs.* the 2nd or 1st tertiles).
140 Subsequently, for a given food group, we investigated to what extent being a consumer at 9 months
141 (or having a high level of consumption) predicted being a consumer at 18 months (or displaying a
142 high level of consumption) using logistic regression analysis. Odds-ratios (ORs) with 95%
143 confidence intervals (CIs) were calculated. Child age at both T2 and T3 was accounted for in all
144 models (one for each food group), as the strength of tracking depends on both the age at baseline
145 and the length of the follow-up⁽²⁶⁾, which varied slightly between children in the current study
146 (Table 1). Analyses were also adjusted for gender due to differences in intakes between boys and
147 girls (not shown). For assessment of tracking of nutrient intakes, nutrients were adjusted for age and
148 gender using the residual method⁽³⁵⁾, and Pearson partial correlation coefficients were calculated
149 between adjusted nutrient intakes at 9 and 18 months. Recommendations for interpreting these
150 correlation coefficients are the following: low <0.3; moderate 0.3-0.6; and high >0.6⁽²⁶⁾. All
151 analyses accounted for clustering of participants in first time parents' groups. Other methods for
152 assessing tracking (e.g. changes in quantiles along with the associated Cohen's Kappa coefficient;
153 or the Kendall rank correlation coefficient) do not allow for adjustment for potential confounders:
154 age and time between the two measurements of diet were considered as important confounders to
155 include in the current analysis.

156 The significance level was set at 5%. Analyses were conducted using Stata software (Release 11;
157 StataCorpLP, College Station, TX, USA).

158

159

160 **Results**

161 *Sample characteristics*

162 Demographic characteristics of the sample are shown in Table 1. It should be noted that the 94
163 children of the control arm who were excluded from the analyses due to loss at follow-up or based
164 on exclusion criteria, came from families where the mothers were less likely to have achieved a
165 high education level (43.8% vs. 63.3%).

166

167 *Dietary intakes*

168 Overall, excluding water intake, foods represented on average 40.5% and 56.7% of total food and
169 beverage intake (in grams) in children aged 9 months and 18 months, respectively. Nearly half of
170 the infants were still breastfed at 9 months, reducing to 9% at 18 months (Table 2). Most of the
171 infants already consumed water, cereal-based products, meat or poultry, fruits, vegetables and dairy
172 foods when aged 9 months. The amounts consumed for these groups increased with age, with the
173 exception of fish (similar amounts at both ages) and vegetables (lesser amounts at 18 months). This
174 decrease in vegetable consumption was consistent with findings amongst consumers only
175 (Supplementary Table). The proportions of children consuming sweetened beverages, savoury and
176 sweet energy-dense snacks, meat products, egg products, and milk increased more than two fold
177 between 9 and 18 months (Table 2). Similar results were observed when the 20 infants with 2
178 recalls only were excluded from the analysis (results not shown).

179 For most of the foods, being a consumer, or consuming larger amounts at 9 months, was
180 predictive of a greater level of consumption 9 months later. The association was stronger for fruits,
181 water, sweetened beverages, dairy foods, egg products, animal products, sweet energy-dense
182 snacks, baby foods in jars, formula, vegetables, fish, and meat and poultry (by descending order,
183 and ORs>0.20) than for other foods/beverages. Similar results were observed when these
184 multivariable analyses were further adjusted for energy intake (results not shown).

185

186 *Nutrient intakes*

187 Energy intake increased by 30% from 9 to 18 months (Table 3). Absolute intakes of protein, fibre,
188 magnesium, sodium, folate and riboflavin increased even more, with sodium increasing the most
189 (114%). The energy density of the diet also increased (36%) between infancy and toddlerhood. For
190 nutrients with available EARs, the proportion of the sample with inadequate intakes was relatively
191 low (0 to 36%)⁽³⁶⁾. Regarding the other micro-nutrients, estimated mean intakes were generally
192 higher than the AIs (or quite close).

193 Amongst the nutrients assessed by the current study, tracking was found to be moderate for
194 riboflavin, iodine, fibre, fibre, calcium, and iron (rho ranging from 0.30 to 0.37, $p < 0.001$). Tracking
195 was low but close to $\rho = 0.3$ for zinc, magnesium, and potassium intakes. Similar results were
196 observed when tracking was assessed using nutrients further adjusted for energy intake (results not
197 shown).

198

199 **Discussion**

200 The present study provides important insights into the dietary intakes of Australian children under 2
201 years of age and how these dietary intakes track during the transition from infancy to toddlerhood.
202 To our knowledge, this has not been described previously using longitudinal data collected at the
203 individual level based upon multiple 24-hour recalls.

204

205 Overall, our findings confirm that the period between 9 and 18 months is a time of significant
206 dietary transition. While milk intake (all sources included) was still greater than the intake of solids
207 at 9 months (expressed in grams), this was no longer the case 9 months later. Along with this
208 weaning process, some typical baby foods (e.g. baby foods in jars, formula, breast-milk) were
209 displaced by foods from the family diet, as shown by the change in food group consumption rates
210 between the two ages (Table 2).

211 In addition to complementary foods, 46% and 9% of the mothers were still breastfeeding at 9 and
212 18 months respectively. Few publications have reported the prevalence of breastfeeding after 6
213 months: similar rates of partly breast-fed infants were reported in Denmark⁽¹⁴⁾, but lower rates were
214 described in the United States (33% and 3% at 9 months and 18 months, respectively)⁽¹³⁾, and in
215 England (2% at 18 months)⁽¹²⁾. Most of the infants consumed a variety of recommended items such
216 as water, cereal-based products, meat or poultry, fruits, vegetables and dairy foods when aged 9
217 months, and the proportion of children consuming these foods remained high at 18 months.
218 However, percentages of consumers of less healthy food groups increased more than two-fold
219 between 9 and 18 months, including items such as sweetened beverages, meat products, savoury
220 and sweet energy-dense snacks. The corresponding quantitative intakes are high considering that
221 these foods are predominantly energy-dense, nutrient-poor and therefore not essential for growth. In
222 addition, they are likely to displace foods of better nutritional quality⁽³⁷⁾, leading to a diet of higher
223 energy density. It is also noteworthy that the consumption of vegetables actually decreased between
224 the two ages, consistent with findings in children aged 24-30 months⁽³⁸⁾. While these results are not
225 easily comparable to other studies due to differences in methodology, 'extra' foods (energy-dense,

226 nutrient-poor) have previously been shown to contribute substantially to the diet in other studies
227 involving children <2y^(13,15,17).

228 Frequent exposure to specific foods during infancy has been shown to influence taste
229 development and later food preferences⁽²⁾. This early learning is influenced by genetic
230 susceptibilities, which include the innate preference for both sweet and salty tastes, and the rejection
231 of sour and bitter flavours⁽¹⁾. New experiences and competencies influence the transition from a
232 milk diet to a solid and diversified diet. Familiarity with specific foods - even in small amounts -
233 appears likely to influence infants' preferences⁽³⁹⁾. Exposing infants and toddlers to energy-dense
234 snacks of high palatability is therefore likely to negatively influence later food preferences and
235 dietary habits⁽⁴⁰⁾. Conversely, early and frequent exposure to fruits and vegetables has been
236 suggested to increase their consumption in later life^(41,42,43). This is all the more important since our
237 findings suggest that some of these food intakes already track highly between infancy and
238 toddlerhood. This is the case not only for energy-dense, nutrient-poor foods (in particular sweet
239 energy-dense snacks and sweetened beverages), but also for nutrient-dense products, such as fruits,
240 vegetables, dairy foods and fish. Water, the recommended beverage, also tracked highly between
241 these two ages. Similar stability over the second half of infancy (6 to 12 months) has also been
242 shown in the longitudinal Southampton Women's Survey, for both healthy and less healthy dietary
243 patterns⁽²⁵⁾. Therefore, while the overall moderate stability in our study probably relates to the fact
244 that this period covers the transition from weaning foods to table foods, it appears that tracking of
245 key foods starts as soon as weaning begins, and is likely to persist into later childhood⁽²²⁻²⁴⁾. Future
246 research investigating the determinants of tracking of dietary intakes would be of interest.

247
248 The changes in nutrient intakes from 9 to 18 months did not consistently reflect the magnitude of
249 increase of energy intake (30%), suggesting varying trajectories of nutrient density across infancy.
250 Despite methodological differences, nutrient intakes estimated in the current work are similar to
251 those reported in other studies^(9,12,18,20). Overall, when compared to EARs or AIs, our results suggest
252 that the population studied is not at a particular risk for inadequate nutritional intake⁽³⁶⁾, which has
253 also been reported in children aged 2-3 and 4-8 of the 2007 Australian National Children's
254 Nutrition and Physical Activity Survey⁽⁴⁴⁾. However, the relatively high intake of sodium at both 9
255 and 18 months should be noted. While international recommendations regarding upper limits are
256 lacking for infants, it has been suggested in the UK that intakes of sodium should not exceed 400
257 mg/d up to the age of 12 months⁽⁴⁵⁾. In Australia, the Nutrient Reference Values for 1-3 year-olds
258 have suggested an upper limit of 1000 mg/d⁽³³⁾. Based on these two recommendations, more than
259 half of the sample has excessive intakes. Our data also showed that sodium levels increased sharply

260 between infancy and toddlerhood, along with the introduction of foods from the family diet. This is
261 of concern, not only in the short term regarding blood pressure⁽⁴⁶⁾, but also regarding the
262 development of taste⁽⁴⁷⁾ and the subsequent food preferences during childhood and long term eating
263 habits^(1,2). Although salt is found in high concentrations in staple foods like cows' milk and
264 processed grain products, it is also a significant component of savoury snacks, the consumption of
265 which was shown to increase sharply between 9 and 18 months.

266 Tracking of nutrient intakes appeared to be moderate to low, which may be explained by the
267 transition in diet between 9 and 18 months. Nonetheless, some consistency in tracking was
268 suggested between fruits, vegetables, dairy products, eggs, fish, water, and nutrients contained
269 within these foods, such as riboflavin, iodine, fibre, calcium, iron, zinc, magnesium, and potassium.

270

271 *Limitations*

272 Although all socio-economic positions were represented in this study, university educated mothers
273 were over-represented, which may limit the generalizability of these findings. Considering that the
274 quality of infant diets has been shown to positively relate to maternal education^(25,48), we may
275 expect diets of even lower quality in the general population. In addition, dietary recommendations
276 refer to usual nutrient intakes⁽³³⁾, which we were not able to strictly assess using three days of
277 recalls and without accounting for vitamins and minerals provided from supplements.

278 Consequently, comparison with recommendations should be considered with caution. Our
279 assessment of nutrient adequacy based on the AIs should also be considered carefully, since the
280 evidence base for AI is weaker than for EARs. Furthermore, it is acknowledged that sodium intakes
281 can be difficult to estimate due to issues with self-reporting added salt and also the quality of food
282 composition databases⁽⁴⁹⁾. Another limitation of the present study concerns the estimation of mixed
283 dishes (for example recipes including both vegetables and animal products, i.e. meat products, meat
284 and poultry, fish, or egg products). Mixed dishes where animal products were the main component
285 were classified as animal products, while mixed dishes including animal products where vegetables
286 were the major components were classified as vegetables. The coding and classification of mixed
287 dishes is a challenge in dietary assessment and reporting. This may have slightly impacted the
288 precision of the estimation of animal products and vegetable intakes, and thus the assessment of
289 tracking for these specific food groups. Finally, we cannot rule out the possible mis-reporting of
290 dietary intake. However, treatment of "mis-reporters" in studies of <2 y varies in the
291 literature^(12,14,16), with only one study excluding them⁽¹⁶⁾. To date, in this age range, over-reporting
292 appears to be more prevalent than under-reporting, with rates varying between [0-12%] and [11-
293 32%], respectively, depending on the definitions used and the populations studied. A standardized

294 method to define mis-reporting in children's dietary studies is lacking and this issue is even more
295 challenging in infants and toddlers, due to the large day-to-day variability that characterizes their
296 dietary intake⁽⁵⁰⁾. In the absence of a more agreed definition for this age group, we have not
297 excluded mis-reporters, although those reporting extreme energy intakes (mean \pm 3 standard
298 deviations) were excluded. Furthermore, the focus of the current study was to investigate intakes
299 from a longitudinal perspective, and while mis-reporting may be present, we hypothesize that the
300 potential biases may affect the same children at the two points in time⁽⁵¹⁾, and therefore have little
301 influence on our findings with respect to tracking.

302

303 *Conclusion*

304 While overall nutrient intakes estimated in this sample do not indicate an important risk of nutrient
305 deficiency, our findings suggest that sub-optimal food consumption occurs as early as 9 months of
306 age. Tracking of intakes was observed not only for energy-dense, nutrient-poor foods, but also for
307 healthier food choices, along with key nutrients. These findings have implications for public health,
308 since behaviours leading to dietary intake are modifiable⁽⁵²⁾. At this stage of life, dietary intakes are
309 largely influenced by characteristics of the home environment, in particular the foods provided by
310 parents, parental feeding practices and modelling. This study adds evidence to the importance of
311 promoting healthy dietary trajectories focusing on infancy, and involving parents.

312

313 **Authors' contributions**

314 S. L. conducted the statistical analysis, contributed to interpretation of results, drafted and edited the
315 manuscript, and had primary responsibility for final content. S. A. M. led and managed the dietary
316 data collection, guided the statistical analysis, contributed to interpretation of results, drafted and
317 edited the manuscript. A. C. S contributed to the dietary data collection, drafted and edited the
318 manuscript. D. C. guided the statistical analysis, contributed to interpretation of results, drafted and
319 edited the manuscript. K. J. C. was the principal investigator on The Melbourne InFANT Program.
320 She designed and led that study, managed the dietary data collection, guided the statistical analysis,
321 contributed to interpretation of results, drafted and edited the manuscript. All authors have read and
322 approved the final manuscript.

323 **Competing interests:** None of the authors had a conflict of interest.

324 **Sources of support:** S. L. was supported by a Deakin University Alfred Deakin Postdoctoral
325 Fellowship. S. A. M. is supported by an Australian Research Council Future Fellowship. A. C. S.
326 was supported by a Deakin University Postgraduate Research Scholarship. K. J. C. and D. C. were
327 supported by fellowships from the Victorian Health Promotion Foundation.

References

1. Birch LL. Development of food preferences. *Annu Rev Nutr.* 1999;19,41-62.
2. Schwartz C, Scholtens PA, Lalanne A, Weenen H, Nicklaus S. Development of healthy eating habits early in life. Review of recent evidence and selected guidelines. *Appetite.* 2011;57,796-807.
3. Baird J, Fisher D, Lucas P, Kleijnen J, Roberts H, Law C. Being big or growing fast: systematic review of size and growth in infancy and later obesity. *BMJ.* 2005;331,929.
4. Owen CG, Martin RM, Whincup PH, Smith GD, Cook DG. Effect of infant feeding on the risk of obesity across the life course: a quantitative review of published evidence. *Pediatrics.* 2005;115,1367-1377.
5. Gunther AL, Buyken AE, Kroke A. Protein intake during the period of complementary feeding and early childhood and the association with body mass index and percentage body fat at 7 y of age. *Am J Clin Nutr.* 2007;85,1626-1633.
6. Koletzko B, von Kries R, Closa R, Escribano J, Scaglioni S, Giovannini M, *et al.* Lower protein in infant formula is associated with lower weight up to age 2 y: a randomized clinical trial. *Am J Clin Nutr.* 2009;89,1836-1845.
7. Barker DJ, Osmond C, Forsen TJ, Kajantie E, Eriksson JG. Trajectories of growth among children who have coronary events as adults. *N Engl J Med.* 2005;353,1802-1809.
8. Alexy U, Kersting M, Sichert-Hellert W, Manz F, Schoch G. Energy intake and growth of 3- to 36-month-old German infants and children. *Ann Nutr Metab.* 1998;42,68-74.
9. Alexy U, Kersting M, Sichert-Hellert W, Manz F, Schoch G. Macronutrient intake of 3- to 36-month-old German infants and children: results of the DONALD Study. Dortmund Nutritional and Anthropometric Longitudinally Designed Study. *Ann Nutr Metab.* 1999;43,14-22.
10. Devaney B, Ziegler P, Pac S, Karwe V, Barr SI. Nutrient intakes of infants and toddlers. *J Am Diet Assoc.* 2004;104(Suppl 1),14S-21S.
11. Fox MK, Reidy K, Novak T, Ziegler P. Sources of energy and nutrients in the diets of infants and toddlers. *J Am Diet Assoc.* 2006;106(Suppl 1),28S-42S.
12. Cowin I, Emmett P. Diet in a group of 18-month-old children in South West England, and comparison with the results of a national survey. *J Hum Nutr Diet.* 2007;20,254-267.
13. Siega-Riz AM, Deming DM, Reidy KC, Fox MK, Condon E, Briefel RR. Food consumption patterns of infants and toddlers: where are we now? *J Am Diet Assoc.* 2010;110(Suppl 12),38S-51S.
14. Gondolf UH, Tetens I, Michaelsen KF, Trolle E. Dietary habits of partly breast-fed and completely weaned infants at 9 months of age. *Public Health Nutr.* 2012;15(4),578-586.
15. Webb KL, Lahti-Koski M, Rutishauser I, Hector DJ, Knezevic N, Gill T, *et al.* Consumption of 'extra' foods (energy-dense, nutrient-poor) among children aged 16-24 months from western Sydney, Australia. *Public Health Nutr.* 2006;9,1035-1044.
16. Conn JA, Davies MJ, Walker RB, Moore VM. Food and nutrient intakes of 9-month-old infants in Adelaide, Australia. *Public Health Nutr.* 2009;12,2448-2456.
17. Chan L, Magarey AM, Daniels LA. Maternal feeding practices and feeding behaviors of Australian children aged 12-36 months. *Matern Child Health J.* 2011;15,1363-1371.
18. Zhou SJ, Gibson RA, Gibson RS, Makrides M. Nutrient intakes and status of preschool children in Adelaide, South Australia. *Med J Aust.* 2012;196,696-700.

19. Fox MK, Pac S, Devaney B, Jankowski L. Feeding infants and toddlers study: What foods are infants and toddlers eating? *J Am Diet Assoc.* 2004;104(Suppl 1),22S-30S.
20. Butte NF, Fox MK, Briefel RR, Siega-Riz AM, Dwyer JT, Deming DM, *et al.* Nutrient intakes of US infants, toddlers, and preschoolers meet or exceed dietary reference intakes. *J Am Diet Assoc.* 2010;110(Suppl 12),27S-37S.
21. Golley RK, Smithers LG, Mittinty MN, Brazionis L, Emmett P, Northstone K, *et al.* An index measuring adherence to complementary feeding guidelines has convergent validity as a measure of infant diet quality. *J Nutr.* 2012;142(5),901-908.
22. Northstone K, Emmett P. Multivariate analysis of diet in children at four and seven years of age and associations with socio-demographic characteristics. *Eur J Clin Nutr.* 2005;59,751-760.
23. Northstone K, Emmett PM. Are dietary patterns stable throughout early and mid-childhood? A birth cohort study. *Br J Nutr.* 2008;100,1069-1076.
24. Pearson N, Salmon J, Campbell K, Crawford D, Timperio A. Tracking of children's body-mass index, television viewing and dietary intake over five-years. *Prev Med.* 2011;53,268-270.
25. Robinson S, Marriott L, Poole J, Crozier S, Borland S, Lawrence W, *et al.* Dietary patterns in infancy: the importance of maternal and family influences on feeding practice. *Br J Nutr.* 2007;98,1029-1037.
26. Twisk JW, Kemper HC, van Mechelen W, Post GB. Tracking of risk factors for coronary heart disease over a 14-year period: a comparison between lifestyle and biologic risk factors with data from the Amsterdam Growth and Health Study. *Am J Epidemiol.* 1997;145,888-898.
27. Campbell K, Hesketh K, Crawford D, Salmon J, Ball K, McCallum Z. The Infant Feeding Activity and Nutrition Trial (INFANT) an early intervention to prevent childhood obesity: cluster-randomised controlled trial. *BMC Public Health.* 2008;8,103.
28. Hesketh K, Campbell K. Opportunities for intervention research during transitions in the lifecycle: The Melbourne InFANT Program. *Australian Epidemiologist.* 2009;3,30-31.
29. Blanton CA, Moshfegh AJ, Baer DJ, Kretsch MJ. The USDA Automated Multiple-Pass Method Accurately Estimates Group Total Energy and Nutrient Intake. *J Nutr.* 2006;136,2594-2599.
30. Webb K, Rutishauser I, Knezevic N. Foods, nutrients and portions consumed by a sample of Australian children aged 16-24 months. *Nutrition and Dietetics.* 2008;65:56-65.
31. Emmett P, North K, Noble S. Types of drinks consumed by infants at 4 and 8 months of age: a descriptive study. The ALSPAC Study Team. *Public Health Nutr.* 2000;3,211-217.
32. Ledikwe JH, Blanck HM, Kettel Khan L, Serdula MK, Seymour JD, Tohill BC, *et al.* Dietary energy density is associated with energy intake and weight status in US adults. *Am J Clin Nutr.* 2006;83,1362-1368.
33. Australian Government, Department of Health and Aging. Nutrient Reference Values for Australia and New Zealand - Executive Summary. National Health and Medical Research Council, 2005.
34. Institute of Medicine. Dietary Reference Intakes: Applications in Dietary Assessment. National Academy Press: Washington, DC, 2000.
35. Willett W. Nutritional epidemiology. Oxford University Press: New York, Oxford, 1998.
36. Touvier M, Lioret S, Vanrullen I, Bocle JC, Boutron-Ruault MC, Berta JL, *et al.* Vitamin and mineral inadequacy in the French population: estimation and application for the optimization of food fortification. *Int J Vitam Nutr Res.* 2006;76,343-351.
37. Bell AC, Kremer PJ, Magarey AM, Swinburn BA. Contribution of 'noncore' foods and beverages to the energy intake and weight status of Australian children. *Eur J Clin Nutr.* 2005;59,639-645.

38. Skinner JD, Carruth BR, Houck KS, Bounds W, Morris M, Cox DR, *et al.* Longitudinal study of nutrient and food intakes of white preschool children aged 24 to 60 months. *J Am Diet Assoc.* 1999;99,1514-1521.
39. Cooke L. The importance of exposure for healthy eating in childhood: a review. *J Hum Nutr Diet.* 2007;20,294-301.
40. Savage JS, Fisher JO, Birch LL. Parental influence on eating behavior: conception to adolescence. *J Law Med Ethics.* 2007;35,22-34.
41. Skinner JD, Carruth BR, Bounds W, Ziegler P, Reidy K. Do food-related experiences in the first 2 years of life predict dietary variety in school-aged children? *J Nutr Educ Behav.* 2002;34,310-315.
42. Coulthard H, Harris G, Emmett P. Long-term consequences of early fruit and vegetable feeding practices in the United Kingdom. *Public Health Nutr.* 2010;13,2044-2051.
43. Nicklaus S. Children's acceptance of new foods at weaning. Role of practices of weaning and of food sensory properties. *Appetite.* 2011;57,812-815.
44. Australian National Children's Nutrition and Physical Activity Survey. 2007 [<http://www.health.gov.au/internet/main/publishing.nsf/content/phd-nutrition-childrens-survey>], accessed 17th December 2012.
45. Scientific Advisory Committee on Nutrition. Salt and Health. The Stationery Office: London, 2003.
46. Hofman A, Hazebroek A, Valkenburg HA. A randomized trial of sodium intake and blood pressure in newborn infants. *JAMA.* 1983;250,370-373.
47. Stein LJ, Cowart BJ, Beauchamp GK. The development of salty taste acceptance is related to dietary experience in human infants: a prospective study. *Am J Clin Nutr.* 2012;95,123-129.
48. Hendricks K, Briefel R, Novak T, Ziegler P. Maternal and child characteristics associated with infant and toddler feeding practices. *J Am Diet Assoc.* 2006;106(Suppl 1),135S-148S.
49. Caggiula AW, Wing RR, Nowalk MP, Milas NC, Lee S, Langford H. The measurement of sodium and potassium intake. *Am J Clin Nutr.* 1985;42,391-398.
50. Livingstone MB, Robson PJ. Measurement of dietary intake in children. *Proc Nutr Soc.* 2000;59,279-293.
51. Black AE, Cole TJ. Biased over- or under-reporting is characteristic of individuals whether over time or by different assessment methods. *J Am Diet Assoc.* 2001;101,70-80.
52. Campbell KJ, McNaughton SA, Lioret S, Crawford D, Salmon J, Ball K, *et al.* The Melbourne InFANT Program positively impacts very young children's lifestyle patterns. *Obesity Research and Clinical Practise.* 2011;5(Suppl 1),S4.

Table 1. Characteristics of the sample (n=177)

	%	Mean (sd)
MOTHER		
Age at baseline (yrs)		32.2 (4.4)
BMI ^a before pregnancy (kg/m ²)		23.9 (4.6)
Duration of pregnancy (weeks)		38.7 (2.4)
Education level		
Low (secondary school or below)	18.1	
Intermediate (trade and certificate qualifications)	18.6	
High (university degree or higher)	63.3	
Country of birth		
Australia	79.7	
Other	20.3	
Language spoken at home		
English	94.9	
Other	5.1	
CHILD		
Sex		
Male	52.0	
Female	48.0	
Birth weight (kg)		3.4 (0.6)
First follow-up, T2		
Age (months)		9.3 (0.8)
Age when first introduced to solid foods (months)		5.3 (0.8)
Weight (kg)		8.9 (1.1)
Second follow-up, T3		
Age (months)		17.8 (1.0)
Time between T2 and T3		8.5 (0.7)
Weight (kg)		11.3 (1.3)

^aBody mass index (BMI) was calculated as weight/height² (kg/m²).

Table 2. Daily food intakes in children aged 9 and 18 months of age and tracking between these two ages (n=177)

Food groups	9 months (T2)				18 months (T3)				Odds of high consumption at 18 months compared to 9 months, OR (CI95%) ^a
	Consumers %	Intakes (grams)			Consumers %	Intakes (grams)			
		Median	IQR	66.7 th percentile		Median ^b	IQR	66.7 th percentile	
Sweetened beverages ^c	13.0	0	0; 0		31.1	0***	0; 7.5		3.50 (1.26; 9.77)*
Water ^d	96.0	106.7	50.0; 185.8	143.3	100	300.0***	208.3; 433.3	400.0	3.91 (1.69; 9.05)**
Cereal-based products ^d	96.6	31.9	15.2; 59.6	46.8	100	90.4***	63.4; 118.2	108.9	1.29 (0.67; 2.46)
Savoury energy-dense snacks ^e	19.8	0	0; 0		63.3	9.5***	0; 33.2	23.2	1.51 (0.61; 3.71)
Sweet energy-dense snacks ^e	38.4	0	0; 3.33		86.4	20.0***	8.0; 46.7	37.0	2.59 (1.15; 5.83)*
Fats and spreads ^e	53.7	0.2	0; 2.4		87.6	2.8***	1.0; 7.2	5.1	1.30 (0.71; 2.38)
Meat products ^c	12.4	0	0; 0		46.9	0***	0; 10.0		1.87 (0.68; 5.11)
Meat and poultry ^d	81.4	15.2	2.3; 40.4	31.0	81.4	24.3**	8.0; 54.0	41.0	2.14 (1.21; 3.81)*
Fish ^c	32.8	0	0; 5.1		35.0	0	0; 9.0		2.22 (1.10; 4.50)*
Egg products ^c	11.3	0	0; 0		28.2	0***	0; 5.4		3.11 (1.14; 8.39)*
Animal products ^d (meat products, meat and poultry, fish, and egg products)	89.3	23.5	6.9; 48.0	39.5	96.6	47.7***	25.6; 78.4	67.1	2.83 (1.49; 5.38)**
Fruits ^d	94.9	66.3	29.4; 130.2	113.5	98.3	144.5***	81.7; 215.3	184.3	4.13 (2.16; 7.91)***
Vegetables ^d	94.9	84.3	37.4; 134.0	112.3	94.9	69.9*	30.5; 124.6	104.9	2.27 (1.12; 4.62)*
Dairy foods ^d	88.1	46.5	11.8; 80.0	68.0	96.0	63.3***	29.4; 111.2	91.7	3.26 (1.69; 6.29)***
Baby foods in jars ^f	89.8	47.4	8.2; 107.1	82.6	50.8	0.7***	0; 30.7		2.35 (1.26; 4.39)*
Breast milk ^f	46.3	0	0; 343.3		8.5	0***	0; 0		nd
Infant or toddler formula ^f	71.2	461.1	0; 686.7	615.7	15.8	0***	0; 0		2.30 (1.12 ; 4.72)*
Milk ^e	46.3	0	0; 42.9		91.0	351.9***	151.1; 524.0	464.7	1.95 (0.98 ; 3.90)

IQR, Inter-quartile Range; OR, Odd-Ratio.

^a Adjusted for age at T2, age at T3, and gender: *P < .5; **P ≤ .01; ***P ≤ .001.

^b Wilcoxon signed rank tests assessing the difference in intakes between 9 and 18 months: *P < .5; **P ≤ .01; ***P ≤ .001.

^c Binomial variables defined at both 9 months (T2) and 18 months (T3) as “consuming (yes, no)”.

^d Binomial variables defined at both T2 and T3 as “high level of consumption” (3rd tertile) vs. “intermediate or low levels of consumption” (2nd or 1st tertiles). Cut-offs corresponding to the 66.7th percentile are reported in the table.

^e Binomial variables defined at T2 as “consuming (yes, no)”; and at T3 as “high level of consumption” (3rd tertile) vs. “intermediate or low levels of consumption” (2nd or 1st tertiles). Cut-offs corresponding to the 66.7th percentile are reported in the table.

^f Binomial variables defined at T2 as “high level of consumption” (3rd tertile) vs. “intermediate or low levels of consumption” (2nd or 1st tertiles); and at T3 as “consuming (yes, no)”. Cut-offs corresponding to the 66.7th percentile are reported in the table.

Table 3. Daily nutrient intakes in children aged 9 and 18 months of age and tracking between these two ages (n=177)

Nutrients	Reference values for Australia and New Zealand (7-12 months)	Intakes at 9 months (T2)			Reference values for Australia and New Zealand (1-3 years)	Intakes at 18 months (T3)			Tracking between 9 and 18 months, rho ^b			
		Inadequacy of intakes, % (CI95%)	Median	Mean		SD	Inadequacy of intakes, % (CI95%)	Median		Mean ^a	SD	
Energy, KJ/day	3100 and 2800 (EER, boys and girls)		3430.1	3453.7	792.9	4000 and 3800 (EER, boys and girls)		4408.4	4473.3***	779.4	0.25***	
Energy density, KJ/100g	None set		417.4	432.8	102.8	None set		582.4	586.6***	114.6	0.19*	
Macro-nutrients												
Fibre, g/day	None set		7.2	8.3	4.2	14 (AI)		12.3	12.6***	4.1	0.35***	
Carbohydrates, g/d	95 (AI)		98.0	98.5	24.0	None set		128.3	128.2***	24.8	0.28***	
Proteins, g/day	14 (AI)		27.4	29.0	10.9	12 (AI)		45.2	46.8***	12.1	0.24**	
Saturated fat, g/d	None set		17.5	17.5	5.2	None set		19.4	19.8***	5.2	0.20**	
Total fats, g/day	30 (AI)		32.2	33.4	8.0	None set		38.1	38.9***	9.3	0.17*	
Micro-nutrients												
Riboflavin, mg/d	0.4 (AI)		1.5	1.4	0.6	0.4 (EAR)		0	2.1	2.1***	0.7	0.37***
Iodine, µg/d	110 (AI)		95.4	99.6	30.4	65 (EAR)	9.6 (4.9; 14.3)	115.9	119.7***	42.8	0.35***	
Calcium, mg/day	270 (AI)		626.8	643.8	257.0	360 (EAR)	4.0 (0.7; 7.2)	766.1	773.6***	229.4	0.30***	
Iron, mg/day	7 (EAR)	35.6 (26.4; 44.7)	8.8	8.7	4.6	4 (EAR)	10.7 (5.4; 16.0)	6.2	6.5***	2.3	0.30***	
Zinc, mg/d	2.5 (EAR)	9.0 (4.2; 13.8)	5.8	5.8	2.4	2.5 (EAR)	0	6.2	6.5***	1.8	0.29***	
Magnesium, mg/d	75 (AI)		110.9	112.5	36.3	65 (EAR)	0	171.5	174.1***	38.7	0.29***	
Potassium, mg/d	700 (AI)		1307.6	1355.1	421.8	2000 (AI)		1815.3	1854.9***	407.2	0.29***	
Beta-carotene ^c , µg/d	None set		1834.6	2378.7	1884.5	None set		1251.3	1606.9***	1133.1	0.24**	
Niacin (equivalents), mg/d	4 (AI)		20.5	20.3	8.5	5 (EAR)	0	24.1	24.8***	6.6	0.24**	
Vitamin A (retinol)	430 (AI)		403.3	409.9	128.8	210 (EAR)	9.6 (5.5; 13.7)	343.7	345.4***	116.4	0.23***	

Nutrients	Reference values for Australia and New Zealand (7-12 months)	Intakes at 9 months (T2)				Reference values for Australia and New Zealand (1-3 years)	Intakes at 18 months (T3)				Tracking between 9 and 18 months, rho ^b
		Inadequacy of intakes, % (CI95%)	Median	Mean	SD		Inadequacy of intakes, % (CI95%)	Median	Mean ^a	SD	
equivalents), µg/d											
Folate (dietary folate equivalents), µg/d	80 (AI)		142.0	160.9	72.2	120 (EAR)	1.1 (0; 2.7)	290.7	309.4***	130.4	0.22***
Thiamin, mg/d	0.3 (AI)		1.0	1.0	0.5	0.4 (EAR)	4.0 (0.8; 7.1)	1.1	1.1	0.5	0.22**
Sodium, mg/d	170 (AI)		469.2	498.7	224.7	200-400 (AI)		1043.1	1065.0***	314.2	0.16*
Vitamin C, mg/d	30 (AI)		97.4	102.0	44.0	25 (EAR)	13.6 (8.2; 18.9)	51.6	58.2***	35.9	0.06
Vitamin E ^c , mg/d	5 (AI)		8.0	7.4	4.3	5 (AI)		3.1	3.6***	2.0	0.02

EER, Estimated Energy Requirement; AI, Adequate Intake; EAR, Estimated Average Requirement.

^a Paired t- tests assessing the difference in intakes between 9 and 18 months: *P < .5; **P ≤ .01; ***P ≤ .001.

^b Pearson correlation of linear regression predicted residuals of nutrients at 9 and 18 months using age and gender as covariates; *P < .5; **P ≤ .01; ***P ≤ .001.

^c Log-transformed intakes.

Appendix A. Food classification

Food groups	
Sweetened beverages	Fruit juices; cordials; soft drinks; and flavored mineral waters
Water	Plain water (tap or bottled).
Cereal-based products	Breakfast cereals; porridge; cereal flours; grains; starches; bread; crackers; and pasta.
Savory energy-dense snacks	Savory bread products; fast-food savory dishes (such as pizzas, sandwiches, hamburgers); chips; and savory snacks.
Sweet energy-dense snacks	Sweet biscuits; cakes; pastries; batter-based products; dairy desserts (frozen milk products, custards, others milk-based desserts, flavored milks); sugar products; and confectionery.
Fats and spreads	Fats; oils; cream; sauces; and salad dressings.
Meat products	Sausages; processed meats; and mixed dishes where pork, bacon, or ham is the major component.
Meat and poultry	Meat (beef, lamb, pork, veal); poultry; game products; organ meat and offal; and mixed dishes where meat, poultry or game is the major component.
Fish	Fish; seafood products; and mixed dishes with fish or seafood as the major component.
Egg products	Eggs; and dishes where egg is the major component.
Animal products	Sum of the 4 preceding groups, i.e. meat products, meat and poultry, fish, and egg products.
Fruits	Fruits; dried fruits; preserve fruits; and mixed dishes where fruit is the major component.
Vegetables	Vegetables; non-fat potatoes; legumes and pulses; mixed dishes where vegetables or legumes are the major components; and soups.
Dairy foods	Yogurts and cheese.
Baby foods in jars	Infant cereal products; infant dinners; and infant desserts.
Breast milk	A feed of 10 minutes or greater was estimated at 100mls and for feeds less than ten minutes, a conversion factor of 10mls per minutes was used. If breast milk was expressed, volumes estimated by parental report were used. ²⁶
Infant or toddler formula	Cow's milk or soy based.
Milk	Cow, sheep and goat milks.