



Choline intakes of Australian children 6-24 months

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by N.A Moumin and T.J. Green

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Foreword

This project was conducted to estimate usual choline intake in Australian children aged 6-24 months and the proportion of the population meeting dietary recommendations set by the National Health and Medical Research Council. Choline values obtained from the 2011-13 Australian Food, Nutrient and Supplement (AUSNUT) database and SAHMRI commercial infant and toddler foods database were applied to dietary data collected during the 2021 Australian Feeding Infants and Toddlers Study (OzFITS 2021).

This project was funded from industry revenue which is matched by funds provided by the Australian Government.

This report is an addition to Australian Eggs Limited's range of peer reviewed research publications and an output of our R&D program, which aims to support improved efficiency, sustainability, product quality, education and technology transfer in the Australian egg industry.

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We would also like to thank the follow up study team which consisted of Professor Tim Green, Dr Najma Moumin, Dr Jo Zhou, and Miss Zhixiao Li.

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Dr Najma Moumin is a registered nutritionist with expertise in population and public health research. She completed a Master in Public Health degree at Simon Fraser University (Canada) in 2016. In March 2023, Najma was awarded a PhD in Medicine from the University of Adelaide. Her PhD project was the first Australia-wide study assessing early life feeding practices and nutrient intakes in children aged < 2 years. Her research provides critical information relevant to public health policy such as the prevalence of food allergy, breastfeeding rates and use of breastmilk substitutes, and the nutritional adequacy of contemporary diets.

Professor Tim Green is a Professor in the College of Nursing and Health Sciences at Flinders University and faculty member in the Women and Kids Theme at SAHMRI. Previously he was a Principal Nutritionist at SAHMRI Women and Kids (2016-2023) and prior to that a Professor of Human Nutrition at the University of British Columbia (BC) and a Scientist at BC's Child and Family Research Institute. His research focuses on micronutrients in pre-pregnancy, pregnancy, lactation, and early life (the first 1000 days), with studies conducted in Canada, New Zealand, Asia and Africa. His research group seeks to identify micronutrient deficiencies through nutrition surveys, better define micronutrient requirements and pregnancy outcomes in these groups through randomised controlled trials and develop sustainable strategies to improve micronutrient status.

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Abbreviations

AUSNUT	Australian Food, Supplement and Nutrient
FSANZ	Food Standards Australia New Zealand
OzFITS	Australian Feeding Infants and Toddlers Study
AI	Adequate Intake

Executive Summary

Despite the important role choline plays in child development, there is limited data on dietary choline intake in early childhood. In this cross-sectional study, we estimated the usual total choline intake, the proportion meeting the recommended intake, and the main dietary sources of choline in infants 6-12 months (n=286) and toddlers 12-24 months (n=475) of age. Dietary data collected using a 24-hour food record were obtained from the 2021 Australian Feeding Infants and Toddlers Study (OzFITS 2021). The mean choline intake was 142 ± 1.9 mg/day in infants and 181 ± 1.2 mg/day in toddlers. Only 35% of infants and 23% of toddlers met the Adequate Intake (AI) for choline based on Nutrient Reference Values for Australia and New Zealand. Breastmilk was the leading source of choline, contributing 42% and 14% of total choline intake in infants and toddlers, respectively; however, egg consumers had the highest adjusted choline intakes and probability of meeting the AI. Results suggest that choline intake may be inadequate in Australian infants and toddlers. Further research to examine the impact of low choline intake on child development is warranted.

Overall Conclusions

- Mean choline intakes were below the recommended Adequate Intake for both age groups.
- Consumption of choline rich foods, including egg, were low overall among Australian infants 6-12 months and toddlers 12-24 months of age.
- Further research is needed to determine the impact of low choline intake on child development, particularly neurodevelopment.

1 Role of choline

Choline has several biological functions including lipid transport, maintenance of the structural integrity of cell membranes, and DNA methylation (Wiedeman et al., 2018a, Zeisel, 2000). Most importantly, choline is a precursor for acetylcholine synthesis, a key neurotransmitter involved in learning, memory, and muscle coordination (National Institutes of Health (NIH) Office of Dietary Supplements (ODS), 2022, Wiedeman et al., 2018a, Zeisel, 2000). Although choline can be synthesized endogenously in the liver, the amount produced is insufficient to meet physiological needs and the remainder must be sourced from the diet (National Institutes of Health (NIH) Office of Dietary Supplements (ODS), 2022, Zeisel, 2000). Animal source foods such as meat, fish, poultry, eggs and dairy are higher in choline than plant-based sources, particularly the fat-soluble forms phosphatidylcholine and sphingomyelin; however, choline also exists in water-soluble forms such as free choline, phosphocholine and glycerophosphocholine (Wiedeman et al., 2018a, Zeisel and Corbin, 2012).

During periods of rapid growth and development, such as the first two years of life, demand for choline is particularly high (Institute of Medicine, 1998, National Health and Medical Research Council, 2006). The 2006 Nutrient Reference Values (NRVs) for Australia and New Zealand (National Health and Medical Research Council, 2006), based on the United States Institute of Medicine Dietary Reference Intakes (Institute of Medicine, 1998), have established recommended population intakes according to age, sex and life stage; however, no studies have investigated dietary choline intakes in young children in Australia. Nutrition surveys conducted in Europe and Canada have shown choline intakes are low with few children aged <3 years meeting recommendations (Vennemann et al., 2015, Wiedeman et al., 2018b), whereas toddlers aged 2-3 years were more likely, than all other age groups, to meet recommendations in the United States National Health and Nutrition Examination Survey 2009-2014 (Wallace and Fulgoni, 2017).

2 Methods

2.1 Study design and participant recruitment

Details of the data collection methods used in OzFITS 2021 can be found at (Moumin et al., 2021, Moumin et al., 2022a). Briefly, OzFITS 2021 was a cross-sectional study designed to assess early feeding practices, food and nutrient intake in Australian children 0-24 months. Recruitment began in April 2020 via targeted online advertising (Trialfacts, 2021); 1140 caregiver-child dyads were enrolled over a 12-month period. The Women's and Children's Health Network Human Research Ethics Committee (HREC/19/WCHN/44) approved the study. Verbal informed consent was obtained from all caregivers prior to data collection.

2.2 Data collection

Data were recorded and managed using a secure, web-based data management system, Research Electronic Data Capture (REDCap) (Harris et al., 2019, Harris et al., 2009).

2.2.1 Caregiver feeding practices

Caregiver feeding practices pertaining to breastfeeding history, breastmilk substitute use, and age of introduction to complementary foods and common food allergens were captured using a telephone-based questionnaire.

2.2.2 Dietary intake data

Caregivers of exclusively breastfed infants were not asked to complete a 24-hour food record as breastmilk alone is sufficient until ~6 months of age. All caregivers of children who received breastmilk substitutes and/or commenced complementary feeding were eligible for a 24-hour food record. Of these, 30% were also randomly assigned to complete another food record. Caregivers recorded all foods, beverages, and dietary supplements consumed by their child from midnight the previous night to midnight the following night on their assigned record-keeping day(s) using the food record booklet and portion estimation guide provided (Anater et al., 2018, Australian Bureau of Statistics, 2014). Breastfeeds were recorded as minutes suckling at the breast between two and ten minutes and converted to a volume of intake (Atkins et al., 2016, Emmett et al., 2000). The amount of breastmilk substitute consumed was calculated as follows: dry powder (g)/ total prepared volume (mL) X prepared volume consumed (mL).

2.2.3 Dietary data entry

Caregivers sent photos or scanned copies of the completed food record booklets via email. Upon receipt, study staff completed a follow-up interview with caregivers to confirm the contents of the food record using the multiple-pass interview method (Raper, 2004). Data were entered directly into Xyris FoodWorks Professional version 10 (Xyris, 2019). Nutrient values were assigned to foods and beverages using the 2011/13 Australian Food, Supplement, and Nutrient Database (AUSNUT) (Food Standards Australia New Zealand, 2013b) and a study specific commercial infant and toddler foods database (Moumin et al., 2020). Food group codes according to the AUSNUT classification system were assigned to foods and recipes (Food Standards Australia New Zealand, 2013a).

Since publication of the original study (Moumin et al., 2022b), choline data has become available in Xyris FoodWorks™. Using the updated 2011/13 AUSNUT data source (Probst et al., 2019), we assigned choline values to dietary data collected in OzFITS 2021. In addition, we updated the commercial infant and toddler foods database with choline values using the recipe approach as previously described (Moumin et al., 2021, Moumin et al., 2022a). Manufacturers of breast-milk substitutes that did not include choline as a nutrient on the nutrient information panel were contacted and asked to provide estimates of naturally occurring choline per 100g product using their product composition information.

2.2.4 Dietary data entry

Using both days' dietary intake data, the distribution of usual choline intake was calculated using the Intake Modelling, Assessment, and Planning Program Software (IMAPP); intra-individual variation intake was removed using the Iowa State University method (Iowa State University, 2015). Adjusted choline intakes were compared to the Australia New Zealand Nutrient Reference Values (National Health and Medical Research Council, 2006) and the probability of being above the AI is reported for infants and toddlers (National Health and Medical Research Council, 2006). Only 6% of caregivers reported supplement use, none of which included choline; therefore, nutrient contribution from supplement use was excluded.

As all caregivers completed at least one day of dietary intake data for their child, classification as a consumer or non-consumer of a food or food-group was based on consumption behaviour on the first day. Descriptive statistics are reported as mean $\pm$ SD or SE, median (IQR), or n (%) as appropriate. All statistical analyses were completed using SPSS Statistics (v29.0, IBM Corp., Armonk, New York).

3 Results

3.1 Participant characteristics

In total, 976 caregivers with children aged 0-24 months were eligible for a food record. Of these, 308 and 542 were caregivers of infants aged 6-12 months and toddlers aged 12-24 months, respectively. 286/308 (93%) caregivers of infants aged 6-12 months completed at least one food record and 102/308 (33%) completed a repeat record on a non-consecutive day. Similarly, 475/542 (88%) of caregivers of toddlers aged 12-24 months completed one food record and 153/542 (28%) completed a second day's intake.

Table 3-1 Participant characteristics of caregiver-child dyads (n=850)

Characteristic	Mean (SD) or n (%)
Caregiver	
Age, years	34 ± 4.6
Education	
Year 10 or 11	7 (1)
Secondary school	40 (5)
Certificate or diploma	167 (20)
Bachelor's degree or above	636 (75)
Annual household income (AUD)	
<40,000	38 (5)
40,001-70,000	95 (11)
70,001-105,000	191 (23)
105,001-205,000	404 (48)
>205,000	110 (13)
Prefer not to disclose	12 (1)
Child	
Age, months (m)	
6-12 m	8.5 ± 1.7
12-24 m	17.7 ± 3.3
Sex (female)	
6-12 m	152 (49)
12-24 m	252 (47)
Confirmed egg allergy	
6-12 m	7 (2)
12-24 m	15 (3)

3.2 Distribution of usual choline intake

Table 3-2 Percentiles of choline intake and the proportion of Australian children aged 6-24 months (n=761) above the Adequate Intake and Upper Limit.¹

	NRV Values		Distribution of choline intake						NRV compliance (%)	
	AI ²	UL ²	10 th	25 th	50 th	Mean ± SE	75 th	90 th	>AI	>UL
<i>Infants 6-12m</i>										
Choline, mg/day	150	--	103	121	139	142 ± 1.9	159	187	35	--
<i>Toddlers 12-24m</i>										
Choline, mg/day	200	1000	147	161	179	181 ± 1.2	198	218	23	0

¹Choline intake data are presented as percentiles of usual intake, mean ± SE, or percentages of NRV. ² National Health and Medical Research Council Nutrient Reference Values for Australia and New Zealand (National Health and Medical Research Council, 2006). NRV, nutrient reference values; AI, adequate intake, UL, tolerable upper level of intake, m, months.

3.3 Adjusted choline intakes of consumers and non-consumers of choline-rich foods

Table 3 summarizes the proportion of infants and toddlers above the AI for choline and their adjusted choline intakes according to consumption of choline rich foods. Infants 6-12 months who consumed eggs, fish/seafood, and dairy milk had consistently higher adjusted choline intakes and were more likely to be above the AI for choline compared to non-consumers of these foods. Similarly, toddlers who consumed eggs and fish/seafood had significantly higher median choline intakes and a greater proportion exceeded the AI compared to non-consumers. Toddlers who consumed breastmilk substitutes had both the lowest adjusted choline intakes and probability of being above AI for choline.

Table 3-3 Percentiles of choline intake and the percentage of children aged 6-24 months above the Adequate Intake consuming or not consuming choline-rich foods.¹

	Consumers			Non-consumers		
	n (%)	Choline (mg/d) 50 th (25 th , 75 th)	%>AI ²	n (%)	Choline (mg/d) 50 th (25 th , 75 th)	%>AI ²
Infants 6-12m (n=286)						
Breastmilk	222 (78)	139 (124, 159)	38	64 (22)	134 (114, 149)	25
Breastmilk substitutes	106 (37)	138 (121, 166)	32	180 (63)	138 (121,159)	37
Meat	62 (22)	144 (131, 175)	45	224 (78)	137 (119,157)	32
Poultry	60 (21)	145 (127, 170)	42	226 (79)	137 (120,156)	33
Fish/Seafood	41 (14)	152 (124, 171)	54	245 (86)	138 (120, 155)	32
Eggs	49 (17)	159 (141, 194)	65	237 (83)	119 (152, 237)	29
Milk	63 (22)	146 (128, 175)	49	223 (78)	138 (120, 155)	31
Yoghurt	118 (41)	142 (127, 173)	44	168 (59)	135 (119, 152)	29
Toddlers 12-24m (n=475)						
Breastmilk	209 (44)	182 (169, 199)	25	266 (56)	177 (157,197)	22
Breastmilk substitutes	89 (19)	175 (157, 193)	16	386 (81)	180 (163, 199)	25
Meat or meat-based	129 (27)	180 (167, 200)	26	346 (73)	179 (160, 198)	22
Poultry	144 (30)	181 (169, 201)	27	331 (70)	179 (160, 196)	21
Fish/Seafood	97 (20)	187 (170, 204)	31	378 (80)	177 (159, 196)	21
Eggs	105 (22)	202 (187, 222)	53	370 (78)	174 (158, 189)	15
Milk	294 (62)	180 (161, 199)	25	181 (38)	178 (162, 196)	20
Yoghurt	253 (53)	179 (162, 196)	22	222 (47)	180 (160, 199)	25

¹Adjusted choline intakes obtained using the Intake Modelling Assessment and Planning Program (IMAPP). ²The AI for choline for infants 6-12m and toddlers 12-24m is 150 mg/d and 200 mg/d, respectively (National Health and Medical Research Council, 2006). AI, adequate intake, m, months.

3.4 Sources of choline

The foods contributing to choline intake on the first day of the food record are presented in Table 3-4 and Table 3-5, along with the amount and % of total choline derived from these sources. Most infants aged 6-12 months 78% (222/286) were breastfed and breastmilk accounted for more than 40% of all choline. Although eggs were consumed by less than one fifth of infants, they were the fourth highest source of choline overall.

Similarly, breastmilk was the leading source of choline among toddlers. Eggs were consumed by only 22% (105/475) but provided over 10% of total choline. Poultry and meat were consumed by less than one third of toddlers and these foods contributed only six per cent of total choline.

Table 3-4 Sources of choline by food or food group in infants aged 6-12 months (n=286).¹

3-digit Food ID Code	Food Group	Choline (mg)	% choline
111	Tea	.20	0.00
113	Fruit and vegetable juices, and drinks	2.03	0.00
117	Waters, municipal and bottled, unflavoured	.00	0.00
118	Other beverage flavourings and prepared beverages	3.38	0.01
121	Flours and other cereal grains and starches	310.43	0.74
122	Regular breads, and bread rolls (plain/unfilled/untopped varieties)	376.96	0.90
123	English-style muffins, flat breads, and savoury and sweet breads	52.66	0.13
124	Pasta and pasta products (without sauce)	87.85	0.21
125	Breakfast cereals, ready to eat	257.34	0.61
126	Breakfast cereals, hot porridge style	161.12	0.38
131	Sweet biscuits	8.49	0.02
132	Savoury biscuits	27.93	0.07
133	Cakes, muffins, scones, cake-type desserts	262.66	0.63
134	Pastries	131.22	0.31
135	Mixed dishes where cereal is the major ingredient	656.07	1.57
136	Batter-based products	523.05	1.25
141	Butters	33.66	0.08
142	Dairy blends	1.06	0.00
143	Margarine and table spreads	.44	0.00
144	Plant oils	.03	0.00
146	Unspecified fats	.01	0.00
151	Fin fish (excluding commercially sterile)	210.53	0.50
152	Crustacea and molluscs (excluding commercially sterile)	66.30	0.16

154	Packed (commercially sterile) fish and seafood	86.71	0.21
155	Fish and seafood products (homemade and takeaway)	257.75	0.62
156	Mixed dishes with fish or seafood as the major component	75.23	0.18
161	Pome fruit	214.59	0.51
162	Berry fruit	208.73	0.50
163	Citrus fruit	116.91	0.28
164	Stone fruit	14.50	0.03
165	Tropical and subtropical fruit	502.58	1.20
166	Other fruit	81.52	0.19
168	Dried fruit, preserved fruit	25.25	0.06
169	Mixed dishes where fruit is the major component	13.45	0.03
171	Eggs	1638.11	3.91
172	Dishes where egg is the major ingredient	1370.25	3.27
181	Beef, sheep and pork, unprocessed	303.93	0.73
183	Poultry and feathered game	870.07	2.08
185	Sausages, frankfurts and saveloys	197.69	0.47
186	Processed meat	20.69	0.05
187	Mixed dishes where beef, sheep, pork or mammalian game is the major component	995.72	2.38
189	Mixed dishes where poultry or feathered game is the major component	700.69	1.67
191	Dairy milk (cow, sheep and goat)	447.82	1.07
192	Yoghurt	889.03	2.12
193	Cream	9.30	0.02
194	Cheese	173.61	0.41
195	Frozen milk products	5.15	0.01
196	Custards	78.66	0.19
197	Other dishes where milk or a milk product is the major component	27.04	0.06
201	Dairy milk substitutes, unflavoured	70.28	0.17
206	Meat substitutes	45.25	0.11
211	Soup, homemade from basic ingredients	461.22	1.10
216	Soup, not commercially sterile, purchased ready to eat	3.90	0.01
221	Seeds and seed products	49.67	0.12
222	Nuts and nut products	218.90	0.52
231	Gravies and savoury sauces	64.29	0.15
233	Salad dressings	2.71	0.01
235	Dips	51.15	0.12
241	Potatoes	286.00	0.68
242	Cabbage, cauliflower and similar brassica vegetables	817.79	1.95

243	Carrot and similar root vegetables	333.47	0.80
244	Leaf and stalk vegetables	33.14	0.08
245	Peas and beans	139.93	0.33
246	Tomato and tomato products	29.68	0.07
247	Other fruiting vegetables	695.19	1.66
248	Other vegetables and vegetable combinations	225.46	0.54
249	Dishes where vegetable is the major component	730.78	1.75
251	Mature legumes and pulses	157.70	0.38
252	Mature legume and pulse products and dishes	232.61	0.56
262	Corn snacks	1.88	0.00
264	Other snacks	.32	0.00
271	Sugar, honey and syrups	.06	0.00
272	Jam and lemon spreads, chocolate spreads, sauces	1.31	0.00
311	Yeast, and yeast vegetable or meat extracts	24.86	0.06
313	Herbs, spices, seasonings and stock cubes	.89	0.00
314	Essences	.00	0.00
315	Chemical raising agents and cooking ingredients	.00	0.00
321	Infant formulae and human breast milk	23480.67	56.10
322	Infant cereal products	250.60	0.60
323	Infant foods	944.79	2.26
324	Infant drinks	.21	0.00

Table 3-5 Sources of choline by food or food group in toddlers aged 12-24 months (n=475).¹

3-digit Food ID Code	Food Group	Choline (mg)	% choline
111	Tea	1.80	0.00
113	Fruit and vegetable juices, and drinks	134.59	0.15
114	Cordials	7.25	0.01
115	Soft drinks, and flavoured mineral waters	.15	0.00
117	Waters, municipal and bottled, unflavoured	.00	0.00
118	Other beverage flavourings and prepared beverages	6.44	0.01
121	Flours and other cereal grains and starches	972.21	1.12
122	Regular breads, and bread rolls (plain/unfilled/untopped varieties)	2172.42	2.49
123	English-style muffins, flat breads, and savoury and sweet breads	894.27	1.03
124	Pasta and pasta products (without sauce)	447.21	0.51
125	Breakfast cereals, ready to eat	1138.64	1.31
126	Breakfast cereals, hot porridge style	575.17	0.66
131	Sweet biscuits	221.23	0.25
132	Savoury biscuits	379.26	0.44
133	Cakes, muffins, scones, cake-type desserts	1010.84	1.16
134	Pastries	607.39	0.70
135	Mixed dishes where cereal is the major ingredient	3856.46	4.42
136	Batter-based products	1268.95	1.46
141	Butters	155.56	0.18
142	Dairy blends	6.78	0.01
143	Margarine and table spreads	18.13	0.02
144	Plant oils	.31	0.00
146	Unspecified fats	.07	0.00
151	Fin fish (excluding commercially sterile)	1654.07	1.90
152	Crustacea and molluscs (excluding commercially sterile)	131.59	0.15
153	Other sea and freshwater foods	52.66	0.06
154	Packed (commercially sterile) fish and seafood	158.51	0.18
155	Fish and seafood products (homemade and takeaway)	601.75	0.69
156	Mixed dishes with fish or seafood as the major component	566.32	0.65
157	Wild caught fish and seafood (Indigenous survey)	19.50	0.02

161	Pome fruit	379.72	0.44
162	Berry fruit	774.93	0.89
163	Citrus fruit	565.08	0.65
164	Stone fruit	124.90	0.14
165	Tropical and subtropical fruit	2022.33	2.32
166	Other fruit	576.77	0.66
167	Mixtures of two or more groups of fruit	10.65	0.01
168	Dried fruit, preserved fruit	201.62	0.23
169	Mixed dishes where fruit is the major component	91.95	0.11
171	Eggs	6653.12	7.63
172	Dishes where egg is the major ingredient	3709.40	4.26
181	Beef, sheep and pork, unprocessed	1443.73	1.66
183	Poultry and feathered game	2513.77	2.88
185	Sausages, frankfurts and saveloys	672.55	0.77
186	Processed meat	811.39	0.93
187	Mixed dishes where beef, sheep, pork or mammalian game is the major component	3177.54	3.65
188	Mixed dishes where sausage, bacon, ham or other processed meat is the major component	33.81	0.04
189	Mixed dishes where poultry or feathered game is the major component	2548.88	2.92
191	Dairy milk (cow, sheep and goat)	9873.94	11.33
192	Yoghurt	3234.05	3.71
193	Cream	38.82	0.04
194	Cheese	1222.01	1.40
195	Frozen milk products	91.34	0.10
196	Custards	48.45	0.06
197	Other dishes where milk or a milk product is the major component	26.32	0.03
198	Flavoured milks and milkshakes	346.18	0.40
201	Dairy milk substitutes, unflavoured	1353.81	1.55
206	Meat substitutes	241.76	0.28
207	Dishes where meat substitutes are the major component	44.86	0.05
211	Soup, homemade from basic ingredients	921.09	1.06
212	Dry soup mix	9.66	0.01
213	Soup, prepared from dry soup mix	13.48	0.02
215	Soup, commercially sterile, prepared from condensed or sold ready to heat	51.55	0.06
216	Soup, not commercially sterile, purchased ready to eat	13.19	0.02
221	Seeds and seed products	193.58	0.22

222	Nuts and nut products	744.55	0.85
231	Gravies and savoury sauces	104.05	0.12
232	Pickles, chutneys and relishes	25.57	0.03
233	Salad dressings	11.10	0.01
235	Dips	235.83	0.27
241	Potatoes	866.58	0.99
242	Cabbage, cauliflower and similar brassica vegetables	874.50	1.00
243	Carrot and similar root vegetables	515.73	0.59
244	Leaf and stalk vegetables	78.07	0.09
245	Peas and beans	415.87	0.48
246	Tomato and tomato products	245.88	0.28
247	Other fruiting vegetables	1520.35	1.74
248	Other vegetables and vegetable combinations	369.24	0.42
249	Dishes where vegetable is the major component	1407.26	1.61
251	Mature legumes and pulses	567.04	0.65
252	Mature legume and pulse products and dishes	1314.29	1.51
261	Potato snacks	12.98	0.01
262	Corn snacks	90.69	0.10
263	Extruded or reformed snacks	31.58	0.04
264	Other snacks	17.92	0.02
271	Sugar, honey and syrups	7.81	0.01
272	Jam and lemon spreads, chocolate spreads, sauces	14.44	0.02
273	Dishes and products other than confectionery where sugar is the major component	6.52	0.01
281	Chocolate and chocolate-based confectionery	30.58	0.04
282	Fruit, nut and seed-bars	2.01	0.00
283	Muesli or cereal style bars	92.29	0.11
284	Other confectionery	.04	0.00
301	Formula dietary foods	.35	0.00
311	Yeast, and yeast vegetable or meat extracts	159.74	0.18
313	Herbs, spices, seasonings and stock cubes	28.08	0.03
321	Infant formulae and human breast milk	14638.73	16.79
322	Infant cereal products	132.27	0.15
323	Infant foods	1516.20	1.74

4 Discussion

This study builds on previous research conducted by our group assessing nutrient intakes in young children to include choline. Adjusted mean choline intakes in infants aged 6-12 months and in toddlers aged 12-24 months were lower than the recommended intakes endorsed by Australia's National Health and Medical Research Council (NHMRC) of 150 and 200 mg/day, respectively (National Health and Medical Research Council, 2006). The proportion of infants and toddlers exceeding the AI was also low at 35% and 23%, respectively. In both age groups, breastmilk was the leading source of choline providing 14-42% of all choline. Other than breastmilk, egg consumers had the highest adjusted choline intakes and were most likely to exceed the AI.

Although no published studies have evaluated choline intakes in infants, our toddler intake data are comparable with those reported in Canada and Europe (Vennemann et al., 2015, Wiedeman et al., 2018b) and are slightly lower than the United States (US) (Wallace and Fulgoni, 2017). In a randomized controlled trial with Canadian toddlers aged 1-2 years supplemented with long-chain polyunsaturated fatty acids (n=110), Wiedeman et al reported mean choline intakes of 174 ± 56 and 205 ± 67.5 mg/day at one year and two years of age, respectively (Wiedeman et al., 2018b). Similarly, mean intakes for toddlers 1 to ≤ 3 years of age from national nutrition surveys conducted in Finland, Germany, Italy, and the United Kingdom ranged from 151-210 mg/day (Vennemann et al., 2015). Intakes did not exceed the AI for most toddlers in Canada and Europe (Vennemann et al., 2015, Wiedeman et al., 2018b), consistent with our findings.

In contrast, Wallace et al reported a higher mean intake (217 ± 3.58) and percentage of toddlers aged 2-3 years above the AI (61%) in the US NHANES 2009–2014 (Wallace and Fulgoni, 2017). This difference may be attributable to age of the children at the time of the survey and differences in food consumption patterns particularly, meat and dairy foods. Indeed, in the 2016 US Feeding Infants and Toddlers Study, Roess et al reported that ~70% of toddlers 1-2 years consumed meat, poultry or fish (Roess et al., 2018). In contrast, only 20-27% of toddlers in our study consumed these foods. Breastmilk substitutes (toddler milks) which are not necessary for toddlers were consumed by one fifth of toddlers which, unlike infant formula (Food Standards Australia New Zealand, 2023), do not contain added choline. Caregivers may benefit from additional guidance on how to prioritise consumption of animal source foods rich in choline and other essential nutrients in the second year of life while continuing to breastfeed, and limit breastmilk substitute use.

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Summary

Project Title:	Eggs to improve choline intakes in young Australian children: providing the evidence
Australian Eggs Limited Project No	GROW018
Researchers Involved	N.A Moumin and T.J. Green
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Objectives	1. Raise awareness of the nutritional value of eggs 2. Identify the gap in choline intake in young Australian children and potential consequences 3. Identify key sources of choline in the diet and provide ways to improve choline intake
Background	Despite the important role choline plays in child development, there are no data on dietary choline intake in early childhood in Australia. In this cross-sectional study, we estimated the usual total choline intake, the proportion exceeding the Adequate Intake (AI), and determined the main dietary sources of choline in infants 6-12 months (n=286) and toddlers 12-24 months (n=475) of age.
Research	A single 24-hour food record with repeats collected during the 2021 Australian Feeding Infants and Toddlers Study (OzFITS 2021) was used to estimate dietary choline intake.
Outcomes	The mean choline intake was 142 ± 1.9 mg/day in infants and 181 ± 1.2 mg/day in toddlers. Only 35% of infants and 23% of toddlers exceeded the Adequate Intake (AI) for choline based on Nutrient Reference Values (NRVs) for Australia and New Zealand. Breastmilk was the leading source of choline, contributing 42% and 14% of total choline intake in infants and toddlers, respectively; however, egg consumers had the highest adjusted choline intakes and probability of exceeding the AI.
Implications	Findings suggest that choline intake may be suboptimal in Australian infants and toddlers. Further research to examine the impact of low choline intake on child development is warranted.
Key Words	Infants; Toddlers; Choline; Dietary Intake; Australia
Publications	Nutrients paper - see page 17



Article

Usual choline intake of Australian children 6-24 months: Findings from the Australian Feeding Infants and Toddlers Study (OzFITS 2021)

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Abstract: (1) Background: Despite the important role choline plays in child development, there is no data on dietary choline intake in early childhood in Australia. (2) Aim: In this cross-sectional study, we estimated the usual total choline intake, the proportion exceeding the Adequate Intake (AI), and determined the main dietary sources of choline in infants 6-12 months (n=286) and toddlers 12-24 months (n=475) of age. (3) Methods: A single 24-hour food record with repeats collected during the 2021 Australian Feeding Infants and Toddlers Study (OzFITS 2021) was used to estimate dietary choline intake. (4) Results: The mean choline intake was 142 ± 1.9 mg/day in infants and 181 ± 1.2 mg/day in toddlers. Only 35% of infants and 23% of toddlers exceeded the Adequate Intake (AI) for choline based on Nutrient Reference Values (NRVs) for Australia and New Zealand. Breastmilk was the leading source of choline, contributing 42% and 14% of total choline intake in infants and toddlers, respectively; however, egg consumers had the highest adjusted choline intakes and probability of exceeding the AI. (5) Conclusions: Findings suggest that choline intake may be suboptimal in Australian infants and toddlers. Further research to examine the impact of low choline intake on child development is warranted.

Keywords: Infants; Toddlers; Choline; Dietary Intake; Australia

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1. Introduction

Choline is required for lipid transport, maintenance of the structural integrity of cell membranes, and DNA methylation [1, 2]. Most importantly, choline is a precursor for acetylcholine synthesis, a key neurotransmitter involved in learning, memory, and muscle coordination [1-3]. Although choline can be synthesized endogenously in the liver, the amount produced is insufficient to meet physiological needs and the remainder must be sourced from the diet [2, 3]. Choline exists in both fat-soluble and water-soluble forms. Animal source foods such as meat, fish, poultry, eggs and dairy are higher in choline, particularly the fat-soluble forms phosphatidylcholine and sphingomyelin whereas plant based sources and breastmilk are higher in the water-soluble forms free choline, phosphocholine and glycerophosphocholine [1, 4].

During periods of rapid growth and development such as the first two years of life, demand for choline is particularly high [5, 6]. The 2006 Nutrient Reference Values (NRVs)

for Australia and New Zealand [5], based on the United States Institute of Medicine Dietary Reference Intakes [6], have established Adequate Intakes (AIs) for different life stage groups, including children under 2 years; however, no studies have investigated dietary choline intakes in young children in Australia. Nutrition surveys conducted in Europe and Canada have shown choline intakes are low with few children <3 years the AI [7, 8]. However, toddlers 2-3 years were more likely than all other age groups to be above the AI in the United States National Health and Nutrition Examination Survey 2009-2014 [9].

In 2021 we published the first ever Australia-wide food and nutrient intake study in children under two years [10, 11], the Australian Feeding Infants and Toddlers Study (OzFITS 2021). However, food composition values for choline were not available in the 2011-13 Australian Food, Supplement and Nutrient Database (AUSNUT) [12] at the time of the analysis and choline intakes were not assessed. Thus, the aims of this study are: 1) to estimate the usual total choline intake of children 6-24 months; 2) to estimate the proportion exceeding the AI; and 3) to determine the major dietary sources contributing to choline intake.

2. Materials and Methods

2.1 Study design and participant recruitment

Details of the data collection methods used in OzFITS 2021 are available elsewhere [10, 13]. Briefly, OzFITS 2021 was a cross-sectional study designed to assess early feeding practices, food and nutrient intake in Australian children 0-24 months. Recruitment began in April 2020 via targeted online advertising [14]; 1140 caregiver-child dyads were enrolled over a 12 month period. The Women's and Children's Health Network Human Research Ethics Committee (HREC/19/WCHN/44) approved the study. Verbal informed consent was obtained from all caregivers prior to data collection.

2.2 Data collection

Data were recorded and managed using a secure, web-based data management system, Research Electronic Data Capture (REDCap) [15, 16].

2.2.1 Caregiver feeding practices

Caregiver feeding practices pertaining to breastfeeding history, breastmilk substitute use, and age of introduction to complementary foods and common food allergens were captured using a telephone-based questionnaire.

2.2.2 Dietary intake data

Caregivers of exclusively breastfed infants were not asked to complete a 24-hour food record as breastmilk alone is sufficient until ~6 months. All caregivers of children who received breastmilk substitutes and/or commenced complementary feeding were eligible for a 24-hour food record. Of these, 30% were also randomly assigned to complete another food record.

Caregivers recorded all foods, beverages, and dietary supplements consumed by their child from midnight the previous night to midnight the following night on their assigned record-keeping day(s) using the food record booklet and portion estimation guide provided [17, 18]. Breastfeeds were recorded as minutes suckling at the breast between two and ten minutes and converted to a volume of intake [19-21]. The amount of breastmilk substitute consumed was calculated as follows: dry powder (g)/ total prepared volume (mL) × prepared volume consumed (mL).

2.2.3 Dietary data entry

Caregivers sent photos or scanned copies of the completed food record booklets via email. Upon receipt, study staff completed a follow-up interview with caregivers to confirm the contents of the food record using the multiple-pass interview method [22]. Data were entered directly into Xyris FoodWorks Professional version 10 [23]. Nutrient values were assigned to foods and beverages using the 2011/13 Australian Food, Supplement, and Nutrient Database (AUSNUT) [12] and a study specific commercial infant and toddler foods database [24]. Food group codes according to the AUSNUT classification system were assigned to foods and recipes [25].

Since publication of the original study [11], choline data has become available in Xyris FoodWorks™. Using the updated 2011/13 AUSNUT data source published by Probst et al [26], we assigned choline values to dietary data collected in OzFITS 2021. In addition, we updated the commercial infant and toddler foods database with choline values using the recipe approach as previously described [10, 13]. Manufacturers of breastmilk substitutes that did not include choline as a nutrient on the nutrient information panel were contacted and asked to provide estimates of naturally occurring choline per 100g product using their product composition information.

2.2.4 Data analysis

Using both days' dietary intake data, the distribution of usual choline intake was calculated using the Intake Modelling, Assessment, and Planning Program Software (IMAPP); intra-individual variation intake was removed using the Iowa State University method [27]. Adjusted choline intakes were compared to the NRVs for Australia New Zealand [5]. As choline lacks an Estimated Average Requirement (EAR), the probability of being above the AI is reported for infants and toddlers [5]. Only 6% of caregivers reported supplement use, none of which included choline; therefore, nutrient contribution from supplement use was excluded.

As all caregivers completed at least one day of dietary intake data for their child, classification as a consumer or non-consumer of a food or food-group was based on consumption behavior on the first day. The Pearson Chi Square test of independence was used to assess whether consumption of choline-rich foods influenced the likelihood of exceeding the AI for choline. The level of significance was set at 0.05. Descriptive statistics are reported as mean $\pm$ SD or SE, median (IQR), or n (%) as appropriate. All statistical analyses were completed using SPSS Statistics (v29.0, IBM Corp., Armonk, New York).

3. Results

3.1. Participant characteristics

1140 caregiver-child dyads were enrolled in OzFITS 2021, but only 976 were eligible for a food record. Of those eligible for a food record, 308 and 542 were caregivers of infants 6-12 months and toddlers 12-24 months, respectively. Attrition was low with 286/308 (93%, all rounding the percentage) caregivers of infants 6-12 months completing at least one food record and 102/308 (33%) completing a repeat record on a non-consecutive day. Similarly, 475/542 (88%) of caregivers of toddlers 12-24 months completed one food record and 153/542 (28%) completed a second day's intake. Three quarters of caregivers had at least a bachelor's degree and 60% reported household incomes in the top two quintiles. Prevalence of egg allergy was low with 3% (22/850) of caregivers reporting a confirmed allergy.

Table 1. Participant Characteristics of caregiver-child dyads (n=850)

Characteristic	Mean (SD) or n (%)
Caregiver	
Age, years	34±4.6
Education	
Year 10 or 11	7 (1)
Secondary school	40 (5)
Certificate or diploma	167 (20)
Bachelor's degree or above	636 (75)
Annual household income (AUD)	
<40,000	38 (5)
40,001-70,000	95 (11)
70,001-105,000	191 (23)
105,001-205,000	404 (48)
>205,000	110 (13)
Prefer not to disclose	12 (1)
Child	
Age, months	
6-12 m	8.5±1.7
12-24 m	17.7±3.3
Sex (female)	
6-12 m	152 (49)
12-24 m	252 (47)
Confirmed egg allergy	
6-12 m	7 (2)
12-24 m	15 (3)

3.2 Distribution of usual choline intake

The distribution of usual choline intake in infants 6-12 months and toddlers 12-24 months is summarized in Table 2. 761 children who completed the OzFITS 2021 aged 6-24 were included. The proportion of the population above the AI for choline was low in both age groups at 35% and 23%, respectively.

Table 2. Percentiles of choline intake and the proportion of Australian children 6-24m (n=761) above the Adequate Intake and Upper Limit.¹

	NRVs		Distribution of choline intake						NRV compliance (%)	
	AI ²	UL ²	10 th	25 th	50 th	Mean ± SE	75 th	90 th	>AI	>UL
Infants 6-12m										
Choline, mg/day	150	--	103	121	139	142 ± 1.9	159	187	35	--
Toddlers 12-24m										
Choline, mg/day	200	1000	147	161	179	181 ± 1.2	198	218	23	0

¹Choline intake data are presented as percentiles of usual intake, mean ± SE, or percentages of NRV. NRVs, nutrient reference values; AI, adequate intake, UL, tolerable upper level of intake; ²National Health and Medical Research Council Nutrient Reference Values for Australia and New Zealand [5].

3.2. Adjusted choline intakes of consumers and non-consumers of choline-rich foods

Table 3 summarizes the proportion of infants and toddlers above the AI for choline and their adjusted choline intakes according to consumption of choline rich foods. Infants 6-12 months who consumed eggs, fish/seafood, and dairy milk had consistently higher adjusted choline intakes and were more likely to be above the AI for choline compared to non-consumers of these foods. Similarly, toddlers who consumed eggs and fish/seafood

had significantly higher median choline intakes and a greater proportion exceeded the AI compared to non-consumers. Toddlers who consumed formula had both the lowest adjusted choline intakes and probability of being above AI for choline.

Table 3. Percentiles of choline intake and the percentage of children 6–24m (n=761) above the Adequate Intake consuming or not consuming choline-rich foods.¹

	Consumers			Non-consumers			p
	n (%)	Choline (mg/d)	%>AI ²	n (%)	Choline (mg/d)	%>AI ²	
		50 th (25 th , 75 th)			50 th (25 th , 75 th)		
<i>Infants 6-12 (n=286)</i>							
Breastmilk	222 (78)	139 (124, 159)	38	64 (22)	134 (114, 149)	25	0.058
Breastmilk substitutes	106 (37)	138 (121, 166)	32	180 (63)	138 (121,159)	37	0.432
Meat	62 (22)	144 (131, 175)	45	224 (78)	137 (119,157)	32	0.057
Poultry	60 (21)	145 (127, 170)	42	226 (79)	137 (120,156)	33	0.221
Fish/Seafood	41 (14)	152 (124, 171)	54	245 (86)	138 (120, 155)	32	0.007
Eggs	49 (17)	159 (141, 194)	65	237 (83)	119 (152, 237)	29	<0.001
Milk	63 (22)	146 (128, 175)	49	223 (78)	138 (120, 155)	31	0.007
Yoghurt	118 (41)	142 (127, 173)	44	168 (59)	135 (119, 152)	29	0.007
<i>Toddlers 12-24m (n=475)</i>							
Breastmilk	209 (44)	182 (169, 199)	25	266 (56)	177 (157,197)	22	0.430
Breastmilk substitutes	89 (19)	175 (157, 193)	16	386 (81)	180 (163, 199)	25	0.065
Meat	129 (27)	180 (167, 200)	26	346 (73)	179 (160, 198)	22	0.445
Poultry	144 (30)	181 (169, 201)	27	331 (70)	179 (160, 196)	21	0.181
Fish/Seafood	97 (20)	187 (170, 204)	31	378 (80)	177 (159, 196)	21	0.042
Eggs	105 (22)	202 (187, 222)	53	370 (78)	174 (158, 189)	15	<0.001
Milk	294 (62)	180 (161, 199)	25	181 (38)	178 (162, 196)	20	0.271
Yoghurt	253 (53)	179 (162, 196)	22	222 (47)	180 (160, 199)	25	0.434

¹Adjusted choline intakes obtained using the Intake Modelling Assessment and Planning Program (IMAPP); ² AI, adequate intake. The AI for choline for infants 6–12m and toddlers 12–24m is 150 mg/d and 200 mg/d, respectively [5].

3.3 Top sources of choline

Table 4 illustrates the foods or food groups contributing $\geq 5\%$ of total choline and the percentage of all choline derived from these sources for consumers and in the overall population. 78% (222/286) of infants 6–12 months were breastfed and breastmilk accounted for almost 60% of all choline among breastfed infants. Eggs were consumed by less than one fifth of infants, but provided almost one third of the choline among consumers and was the fourth highest source of choline overall.

Similarly, breastmilk was the leading source of choline among toddlers comprising one third of all choline intake among consumers. Although 62% (294/475) of toddlers consumed dairy milk either as a main drink or as a component of a mixed dish, the overall contribution to total choline intake was low at 16%. Conversely, eggs were consumed by only 22% (105/475) of toddlers but provided 40% of all choline among consumers. Poultry and meat were consumed by less than one third of toddlers; among consumers, these food groups contributed less than one fifth of all choline and only 6% overall.

TABLE 4 Sources of choline by food or food group contributing $\geq 5\%$ choline on day one of the food record in Australian children 6–24m (n=761).

Food or food group	Consumers n (%)	Choline intake (mg/d) among consumers 50 th (25 th , 75 th)	Contribution to choline intake (%) among consumers 50 th (25 th , 75 th)	Overall percentage of total choline intake for all participants
Infants 6–12 (n=286)				
Breastmilk	222 (78)	78 (53, 103)	56 (36, 77)	42
Breastmilk substitutes	106 (37)	58 (28, 79)	44 (19, 62)	14
Vegetables	236 (83)	8 (3, 18)	6 (3, 12)	8
Eggs	49 (17)	61 (19, 89)	28 (15, 41)	7
Toddlers 12–24m (n=475)				
Breastmilk	209 (44)	54 (32, 86)	32 (17, 47)	14
Dairy milk	294 (62)	26 (14, 44)	16 (7, 27)	12
Eggs	105 (22)	94 (62, 118)	39 (26, 48)	12
Vegetables	391 (82)	10 (4, 21)	6 (3, 12)	7
Cereal-based dishes	171 (36)	21 (10, 40)	12 (5, 23)	6
Poultry	144 (30)	28 (15, 45)	15 (8, 25)	6
Meat	129 (27)	30 (15, 49)	16 (9, 26)	6
Fruit	449 (95)	9 (5, 15)	5 (3, 9)	5

4. Discussion

This study builds on previous research conducted by our group assessing nutrient intakes in young children to include choline. Adjusted mean choline intakes in infants 6–12 months and toddlers 12–24 months were lower than the recommended intakes endorsed by Australia’s National Health and Medical Research Council (NHMRC) of 150 and 200 mg/day, respectively [5]. The proportion of infants and toddlers exceeding the AI was also low at 35% and 23%. In both age groups, breastmilk was the leading source of choline providing 32–56% of all choline among consumers. Other than breastmilk, egg consumers had the highest adjusted choline intakes and were most likely to exceed the AI.

The AI for choline during lactation is high at 550 mg/day to support both maternal and infant needs [2, 5]. Despite this recommendation, mean choline intakes among lactating women in the 2011/13 Australian National Nutrition and Physical Activity Survey (NNPS) were significantly low at 253 mg/day, with less than 1% exceeding the AI [26]. Maternal diet may influence breastmilk composition for some nutrients [28]; however, the predominant forms of choline found in breastmilk are the water-soluble forms free choline, phosphocholine, and glycerophosphocholine and do not appear to be associated with maternal choline intake [29, 30].

78% (222/286) of infants 6–12 months sourced over half of their daily choline from breastmilk; however, few exceeded the AI as choline-rich complementary foods such as beef (95mg/100g), chicken (117mg/100g), fish (68mg/100g) and egg (230mg/100g)[12] were not frequently consumed. Importantly, foods of animal origin are rich in phosphatidylcholine, the most biologically abundant phospholipid accounting for ~50% of the phospholipids found on cell membranes [2, 31]. Unless acquired from the diet, phosphatidylcholine and sphingomyelin, must be synthesized from choline which is also

a precursor for acetylcholine [3]. Low intake of these fat-soluble forms of choline may have implications for the overall supply of choline, potentially compromising the structural integrity of cellular membranes and/or neurodevelopment [32, 33]; however, further research is needed to determine the optimal ratio of water-soluble and fat-soluble forms of choline for development.

Although no published studies have evaluated choline intakes in infants, our toddler intake data are comparable with those reported in Canada and Europe [7, 8] and are slightly lower than the United States (US) [9]. In a randomized controlled trial with Canadian toddlers 1-2 years supplemented with long-chain polyunsaturated fatty acids (n=110), Weideman et al reported mean choline intakes of 174 ± 56 and 205 ± 67.5 mg/day at one year and two years of age, respectively [8]. Similarly, mean intakes for toddlers 1 to ≤ 3 years from national nutrition surveys conducted in Finland, Germany, Italy, and the United Kingdom (UK) ranged from 151-210 mg/day [7]. Intakes did not exceed the AI for most toddlers in Canada and Europe [7, 8], consistent with our findings.

In contrast, Wallace et al reported a higher mean intake (217 ± 3.58) and percentage of toddlers 2-3 years above the AI (61%) in the US NHANES 2009–2014 [9]. This difference maybe attributable to age of the children at the time of the survey and differences in food consumption patterns particularly, meat and dairy foods. Indeed, in the 2016 US Feeding Infants and Toddlers Study, Roess et al reported that ~70% of toddlers 1-2 years consumed meat, poultry or fish and 83% consumed cow's milk as their main drink [34]. In contrast, only 20-27% of toddlers in our study consumed these foods and 44% received breastmilk as their main milk. After 12 months, the NHMRC Infant Feeding Guidelines recommend cow's milk as a main drink and continued breastfeeding to two years and beyond; breastmilk substitutes are not necessary for otherwise healthy toddlers [35]. Although breastfeeding is encouraged in the second year, average breastmilk intake for breastfed toddlers was nearly twice the amount of cow's milk consumed by toddlers who received cow's milk as a main drink (~340 vs 209 mL/day) [13], and may have displaced consumption of nutritious foods consistent with the Australian Guide to Health Eating [36]. Compared to their non-breastfed counterparts, breastfed toddlers consumed fewer servings of fruit, vegetables, cereals and grains, and dairy foods [13]. Furthermore, breastmilk substitutes (toddler milks) which are not necessary were consumed by one fifth of toddlers which, unlike infant formula [37], do not contain added choline. Caregivers may benefit from additional guidance on how to prioritize consumption of animal source foods rich in choline and other essential nutrients in the second year while continuing to breastfeed, and limit breastmilk substitute use.

Australia is the world capital for food allergy with 1/10 infants diagnosed with an IgE-mediated food allergy by 12 months [38]. To mitigate this, the Australasian Society for Clinical Immunology and Allergy (ASCIA) published new guidelines for the prevention of food allergy in 2016 recommending the introduction to common food allergens before 12 months [39]. To maintain/develop tolerance to these foods, ASCIA further recommends regular consumption (twice weekly) [40]. Compliance with the timing of introduction was high with 95% of OzFITS 2021 participants receiving hen's egg by 12 months [41]; however, the frequency of egg consumption per week in this population is unknown as our dietary survey was limited to two days. Only 2.6% (22/850) of caregivers reported a confirmed egg allergy therefore it's unlikely this contributed to the overall low prevalence of egg consumption and suggests eggs may be infrequently consumed.

A key strength of this study is that it is the first to provide data on the distribution of usual choline intake in infants 6-12 months as well as dietary sources contributing to choline intake. It also adds to the limited body of evidence and provides contemporary intake data from a cohort of Australian toddlers 12-24 months. Nevertheless, our study did have some limitations. Although the United States Institute of Medicine Dietary Reference Intakes, on which the NRVs for Australia and New Zealand are based, identified choline as an essential nutrient in 1998 [6], an estimated average requirement

(EAR) has yet to be established for this nutrient due to limited experimental evidence. As such, AIs based on the median intakes of healthy individuals in a population group are used to describe choline intakes [5]. While intakes above the AI can be assumed to be sufficient, intakes below the AI cannot be used to infer risk of inadequacy [5, 6]. For older infants 7–12 months, the AI is based on the average concentration of choline in breastmilk and adjusted for body size and does not account for choline derived from complementary foods [5, 6]. Similarly, the AI for toddlers 1–3 years is not based on population intakes; rather, it is extrapolated from adults, with adjustments made for body size and growth. We did not measure biomarkers of choline; therefore, we cannot comment on choline status. Choline from breastmilk may have been under or overestimated as the volume equations used to calculate breastmilk intake apply a constant flow rate and do not account for differences in feeding efficiency between children [42]. Finally, caregivers may have underreported unhealthy foods due to social desirability bias; however, energy intakes in our study were on average 10% higher than the estimated energy requirement and 9/10 toddlers consumed discretionary foods higher in saturated fat, added sugar, or salt [11, 13, 43] on the day of the survey, suggesting this was not a problem.

5. Conclusions

Average choline intakes among Australian infants and toddlers were below recommendations and less than one third were above the AI. Breastmilk was the leading source of choline in both age groups; however, egg consumers had the highest adjusted choline intakes and probability of exceeding the AI. Further research to examine the impact of low choline intake on child development is warranted.

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