

# Position Statement on Choline Intake in Australia

2 August 2019

This position statement on choline intake was developed by the *Australian Nutrition Advisory Council for Eggs (ANACE)* to address recent research showing that 90% of Australians are consuming less than the NHMRC adequate intake (AI) amounts for this essential nutrient.<sup>1,2</sup>

## BACKGROUND

Following the publication of new Australian research that choline intakes are lower than the NHMRC adequate intake (AI) amounts<sup>2</sup>, and heightened international focus on this essential nutrient, an expert roundtable was convened on 19 July 2019. The participants discussed Australia's current recommendations for choline intake, whether changes are needed, and the value of elevating awareness of this essential nutrient amongst health care practitioners and consumers. Current dietary intakes, choline status of the Australian population, and the health-related benefits of this essential nutrient were all considered by the panel. The wide-ranging biological functions of choline and the need for additional research were also discussed. The aim was to establish a position statement for choline dietary requirements to provide health care practitioners (HCPs) with evidence-based guidance around this nutrient.

## WHY IS CHOLINE IMPORTANT?

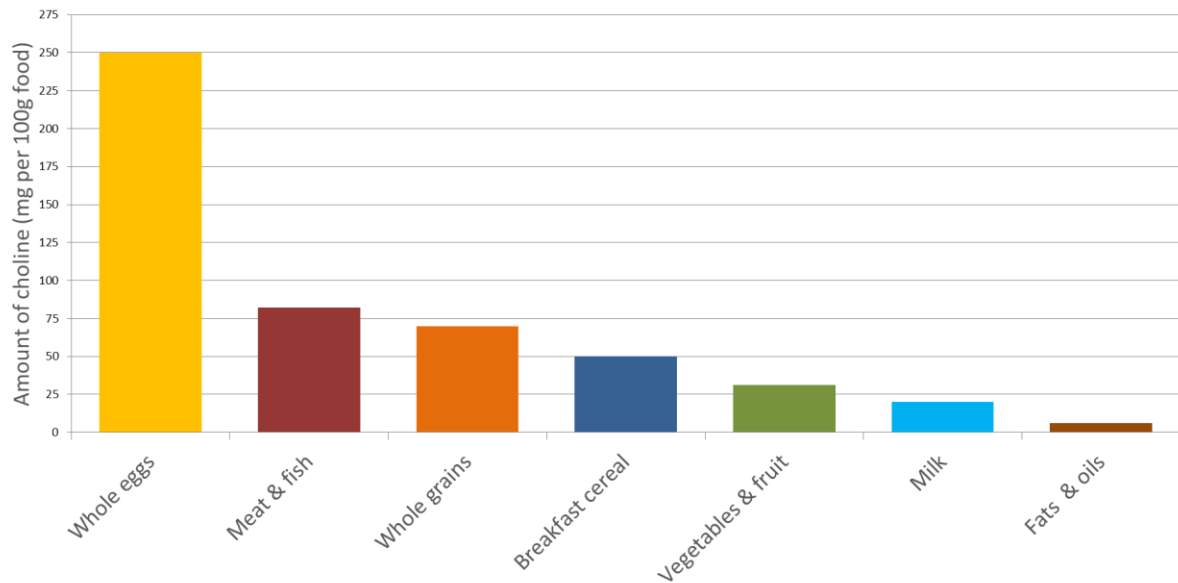
Choline is an essential nutrient involved in many aspects of health and development. As with folate, it is a key methyl group donor important at all life stages. In addition to playing an important role in development overall, during pregnancy choline is critical for appropriate brain and spinal cord development, with some data suggesting that adequate intakes may help to reduce the incidence of birth (neural tube) defects.<sup>3</sup> Emerging research suggests that choline intake during pregnancy may impact cognitive development in childhood (visual memory and processing speed) but further research is urgently needed.<sup>4,5</sup>

Choline is found in high quantities in foods such as eggs, meat, fish and milk (see Figure).<sup>6</sup> Eggs, even when cooked, are the richest food source of choline.

Choline, along with other nutrients (such as DHA, EPA, folate, vitamins B6, B12, C, E and selenium), is important for the structure and function of all cells in the body. Consuming adequate quantities is critical for all cell membrane formation and is necessary to ensure the junctions between nerves work properly (synaptic function) and to regulate nerve messages (neurotransmission); choline also appears to play a role in protecting against neurodegeneration as we age.<sup>7</sup>

Around 10-15% of the population have gene variants (called single nucleotide polymorphisms or SNPs) that reduce the activity of key enzymes in choline metabolism and these individuals may have even higher dietary choline requirements.<sup>8,9</sup> There is no routine test available at present for these genetic variations.

## Choline content of common foods



## CURRENT LOCAL RECOMMENDATIONS

Although some choline can be synthesised in the body, the quantities are insufficient to meet all requirements. As such, sufficient dietary intake is important to maintain appropriate choline levels. The NHMRC published Australian daily nutrient reference values in 2006 (see Table).<sup>1</sup> The values presented are adequate intake (AI) values.

**Table:** Australian NHMRC recommended daily nutrient reference values for choline and percentage of Australian population meeting AI.<sup>1,2</sup>

Age Group	Adequate Intake (AI)	Percent consuming AI
<b>Children</b>		
7-12 months infants	150 mg	No data
1-2 years	200 mg	No data
2-3 years	200 mg	67%
4-8 years	250 mg	20%
<b>Male</b>		
9-13 years	375 mg	7.1%
14-18 years	550 mg	2.0%
19-64 years	550 mg	3.7%
65-85 years	550 mg	1.2%
<b>Female</b>		
9-13 years	375 mg	4.3%
14-18 years	400 mg	1.9%
19-64 years	425 mg	3.3%
65-85 years	425 mg	3.0%
Pregnancy (14-18 years)	415 mg	No data
Pregnancy (19+ years)	440 mg	<1%
Lactation (19+ years)	550 mg	<1%

## INTERNATIONAL RECOMMENDATIONS

In 1998 the US Institute of Medicine (now the National Academy of Medicine) established an adequate intake value for choline as an essential nutrient that must be mostly acquired from the diet.

In 2016 the European Food Safety Authority published Dietary Reference Values for choline, recommending consumption of 400mg per day for adults and 520mg per day for lactating mothers.<sup>10</sup> They state that a cause and effect relationship has been established between the consumption of choline and normal lipid metabolism, maintenance of healthy liver functioning and reduction in homocysteine levels.<sup>11</sup>

At the 2017 American Medical Association Annual Meeting delegates voted in support of a resolution that ‘evidence-based amounts of choline should be included in all prenatal vitamins’.

The American Academy of Pediatrics included choline in their list of recommended nutrients for pregnancy stating that ‘choline is an important nutrient during the first 1000 days of life to support neurodevelopment and lifelong brain health’.<sup>5</sup>

## CHOLINE INTAKE IN AUSTRALIA

New research from the University of Wollongong, NSW, Australia, reported that fewer than 10% of Australians across all age and gender groups were consuming the adequate intake for choline based on NHMRC values (see Table).<sup>2</sup> The authors also found that for most Australians eggs (and foods containing eggs) were the most common choline food source.<sup>2</sup> The study estimated that the average daily amount of choline consumed by Australians was  $265.18 \pm 1.3$ mg (see Table). As a reference, half a fillet of salmon contains approximately 94mg of choline and one large cooked egg contains 147mg of choline.

As choline was not included in Australian food composition tables, a choline database for Australia was developed by expanding the AUSNUT 2011–13 food composition database. This was then used to analyse the Australian National Nutrition and Physical Activity Survey 2011–12 to determine choline consumption. The research has highlighted that few Australians meet the AI values for choline consumption; for example only 1.2% of elderly men (65-85 years) are meeting the AI and <1% of pregnant and lactating women (see Table).

## KEY EVIDENCE-BASED PRACTICE POINTS

- ▶ It is unequivocal that adequate choline levels are essential for a range of cellular functions throughout life.
- ▶ Most Australians are consuming amounts of choline that are well under the adequate intake levels.<sup>2</sup>
- ▶ There is evidence from a small study that in addition to folic acid supplementation, adequate choline intake during pregnancy may further reduce the risk of neural tube defects.<sup>3</sup>
- ▶ One small observational study and one small randomised controlled trial (RCT) linked choline supplementation during pregnancy with improved cognitive outcomes in childhood (visual

memory and processing speed) but further research is needed before conclusions can be drawn.<sup>4,5</sup>

- ▶ Animal studies suggest that adequate choline intake may play a role in preventing dementia and cognitive decline but further research in humans is required.
- ▶ Most prenatal supplements in Australia do not contain choline.
- ▶ Further research into choline is required to fully understand the benefits of optimal choline intake and the implications of consuming less than the AI.

## KEY MESSAGING FOR AUSTRALIAN HEALTH CARE PRACTITIONERS

### Conception & pregnancy

New research suggests that in pregnant women who have sufficient folic acid, increased intake of vitamins B6 and B12, choline, methionine and betaine may offer additional risk reduction for neural tube defects.<sup>3</sup> Australian HCPs should be aware that the two most commonly used prenatal supplement brands in Australia do not contain choline; the supplements that do contain choline only contain very small quantities. Choline is a large molecule and it is difficult to add sufficient quantities to existing one-a-day prenatal tablets. Although choline is available as a separate supplement, purchasing and consuming an additional supplement during pregnancy may be prohibitive for some. As choline is readily available in inexpensive whole-foods such as eggs, meat and fish, this is the simplest and most affordable way for most people to increase their choline levels.

### Lactation

Choline is found naturally in breast milk and breastfed babies get an average of around 107mg of choline per day.<sup>12</sup> There is evidence that inadequate intake of choline in the diet leads to lower levels of choline in breast milk, emphasising the importance of a choline-rich diet for lactating mothers. The Australia New Zealand Food Standards Code legislates that choline is an essential ingredient in infant formula which must contain a minimum of 1.7 mg and maximum of 7.1 mg per 100kJ.

### Infants

There is emerging evidence that adequate dietary choline may play an important role in neurodevelopment and cognitive outcomes from early life.<sup>4,5</sup> It is advisable that choline-rich foods should be included as part of a balanced whole-food diet for all Australians, particularly infants and children. As infants make the transition from breast or formula milk, both of which are rich sources of choline, to solid foods parents and carers should have an awareness of choline-rich food choices as an important part of the diet. Eggs are an inexpensive source of choline that can be easily incorporated into the diet at the appropriate age; milk, fish and meat are other good sources of choline.

### Elderly

Choline may play a role in preventing Alzheimer's disease and cognitive decline, although more research is needed. Choline (400mg) is a key active ingredient in a nutritional supplement which is currently undergoing clinical trials in people with Alzheimer's with promising early findings.<sup>13</sup> It has been reported that Alzheimer's patients have lower levels of choline in their brain and spinal fluid.<sup>14</sup> Choline metabolism gene polymorphisms have also been associated with Alzheimer's disease. Eggs, as a component of a healthy diet, have been associated with improved cognitive function in the

elderly.<sup>15</sup> There is also evidence that a choline-rich diet builds stronger bones<sup>16</sup> and favourable body composition (such as lower BMI and lower waist circumference).<sup>17</sup>

### Vegetarians & vegans

Choline is mainly found in animal-derived foods and therefore people who follow a vegetarian or vegan diet may be at increased risk of not meeting AI levels.<sup>18,19</sup> Eggs and milk are good choline sources for lacto-ovo vegetarians. Plant-based sources of choline include green vegetables, lentils, tofu, nuts, seeds and grains.

## ACTION PLAN FOR FURTHER RESEARCH

- ▶ Raise awareness among HCPs that most Australians are consuming choline at well below the AI.
- ▶ Include information on choline in continuing medical education programs on optimal nutrition at key life stages.
- ▶ Encourage further research to assess the benefits of adequate choline intake and, in particular, to review its importance for a healthy start to life and healthy ageing.
- ▶ Conduct further research to fully ascertain the implications of a low choline diet. Recommendations include: i) systematic literature review and meta-analysis of the existing body of choline research; ii) identification of gaps in the knowledge base; iii) development of protocols for interventions and RCTs; and iv) seeking Australian and International collaborations, and funding, for choline-specific research.
- ▶ Focus on research that improves outcomes for vulnerable life-periods including the first 1000 days of life (covering conception, pregnancy, lactation, and infancy) and explores links between choline deficiency and cognitive decline in the elderly.
- ▶ Recommend that the NHMRC nutrient reference value report is updated to include the most recent choline research.
- ▶ Develop Estimated Average Requirements (EARs) for choline when the research evidence becomes available to establish optimal levels.

## AUTHOR DETAILS

On behalf of the *Australian Nutrition Advisory Council for Eggs*:

Dr Mei Ling Doery, MBBS, BMedSci, MPH

Professor Tim Green, BSc, MSc, PhD, Discipline of Paediatrics, University of Adelaide, South Australia Health & Medical Research Institute, Adelaide, SA

Frances Jewell, BBus, Marketing & Communications Manager, Australian Eggs

Dr Ginni Mansberg, BMed, GAICD, GradDip (Journalism), General Practitioner, Sans Souci Medical Practice, Sydney, NSW

Melanie McGrice, BScNutr, Hons, MNutrDiet, AdvAPD, MAICD, Dietitian, Nutrition Plus Enterprises Pty Ltd, Melbourne, VIC

Sharon Natoli, BSc BNutrDiet, Grad Dip (Bus), Dietitian, Food & Nutrition Australia

Dr Yasmine Probst, MSc (NutrDiet), MHIthInfo, GradCertBus, PhD, FACHI, AdvAPD, Senior Lecturer, University of Wollongong, Wollongong, NSW

Dr Judith Riseley, MBBS, General Practitioner, Glen Waverley, VIC  
Professor Richard Saffery, BSc, PhD, Grad Dip Law (IP), Murdoch Children's Research Institute,  
Melbourne, VIC  
Gemma Wyburn, BNatSci, Grad Dip (Psych), Innovation Program Manager, Australian Eggs

## ACKNOWLEDGEMENTS

We thank Emma Nunan and Yat Shum from opr Agency for stakeholder management, Dr Ruth Hadfield, Mediwrite, for medical writing and A/Prof Justine Waters, Justine Waters Consulting, for meeting facilitation.

## SUGGESTED FURTHER READING

1. National Health and Medical Research Council; Australian Government Department of Health and Ageing; New Zealand Ministry of Health. NHMRC Nutrient Reference Values for Australia and New Zealand, online document <https://www.nhmrc.gov.au/sites/default/files/images/nutrient-reference-dietary-intakes.pdf> [Accessed 20 Jul 2019]. 2006 (updated 2017).
2. Probst Y, Guan V, Neale E. Development of a Choline Database to Estimate Australian Population Intakes. *Nutrients* 2019;11.
3. Petersen JM, Parker SE, Crider KS, Tinker SC, Mitchell AA, Werler MM. One-Carbon Cofactor Intake and Risk of Neural Tube Defects Among Women Who Meet Folic Acid Recommendations: A Multicenter Case-Control Study. *Am J Epidemiol* 2019;188:1136-43.
4. Caudill MA, Strupp BJ, Muscalu L, Nevins JEH, Canfield RL. Maternal choline supplementation during the third trimester of pregnancy improves infant information processing speed: a randomized, double-blind, controlled feeding study. *FASEB J* 2018;32:2172-80.
5. Mun JG, Legette LL, Ikonte CJ, Mitmesser SH. Choline and DHA in Maternal and Infant Nutrition: Synergistic Implications in Brain and Eye Health. *Nutrients* 2019;11.
6. U.S. Department of Agriculture. USDA Database for the Choline Content of Common Foods Release Two, online document <https://www.ars.usda.gov/ARSUserFiles/80400525/Data/Choline/CholIn02.pdf> [Accessed 21 July 2019]. 2008.
7. Bekdash RA. Choline, the brain and neurodegeneration: insights from epigenetics. *Frontiers in Bioscience (Landmark edition)* 2018;23:1113-43.
8. Halova A, Janoutova J, Ewerlingova L, et al. CHAT gene polymorphism rs3810950 is associated with the risk of Alzheimer's disease in the Czech population. *Journal of Biomedical Science* 2018;25:41.
9. Yuan H, Xia Q, Ling K, Wang X, Wang X, Du X. Association of Choline Acetyltransferase Gene Polymorphisms (SNPs rs868750G/A, rs1880676G/A, rs2177369G/A and rs3810950G/A) with Alzheimer's Disease Risk: A Meta-Analysis. *PLoS One* 2016;11:e0159022.
10. EFSA NDA Panel (EFSA Panel on Dietetic Products Nutrition and Allergies). Dietary Reference Values for choline. *EFSA Journal* 2016;14.
11. EFSA NDA Panel (EFSA Panel on Dietetic Products Nutrition and Allergies). Scientific Opinion on the substantiation of health claims related to choline and contribution to normal lipid metabolism (ID 3186), maintenance of normal liver function (ID 1501), contribution to normal homocysteine metabolism (ID 3090), maintenance of no. *EFSA Journal* 2011;9:2056.
12. Wiedeman AM, Whitfield KC, March KM, et al. Concentrations of Water-Soluble Forms of Choline in Human Milk from Lactating Women in Canada and Cambodia. *Nutrients* 2018;10.
13. Dementia Australia. Souvenaid - a dietary treatment for mild Alzheimer's disease, online document [https://www.dementia.org.au/files/helpsheets/Helpsheet-DementiaQandA23-Souvenaid\\_english.pdf](https://www.dementia.org.au/files/helpsheets/Helpsheet-DementiaQandA23-Souvenaid_english.pdf) [accessed 22 July 2019]. 2013 (reviewed 2019).
14. de Wilde MC, Vellas B, Girault E, Yavuz AC, Sijben JW. Lower brain and blood nutrient status in Alzheimer's disease: Results from meta-analyses. *Alzheimers & Dementia (New York, NY)* 2017;3:416-31.
15. Chuang SY, Lo YL, Wu SY, Wang PN, Pan WH. Dietary Patterns and Foods Associated With Cognitive Function in Taiwanese Older Adults: The Cross-sectional and Longitudinal Studies. *Journal of the American Medical Directors Association* 2019;20:544-50.e4.
16. Oyen J, Gjesdal CG, Karlsson T, et al. Dietary Choline Intake Is Directly Associated with Bone Mineral Density in the Hordaland Health Study. *The Journal of Nutrition (Norway)* 2017;147:572-8.
17. Gao X, Wang Y, Randell E, et al. Higher Dietary Choline and Betaine Intakes Are Associated with Better Body Composition in the Adult Population of Newfoundland, Canada. *PLoS One* 2016;11:e0155403.
18. Kim S, Fenech MF, Kim PJ. Nutritionally recommended food for semi- to strict vegetarian diets based on large-scale nutrient composition data. *Scientific Reports* 2018;8:4344.
19. Wallace TC, Blusztajn JK, Caudill MA, et al. Choline: The Underconsumed and Underappreciated Essential Nutrient. *Nutrition Today* 2018;53:240-53.