Literature Review of the Nutritional and Health Benefits of Eggs

Prepared for: Australian Egg Corporation Limited

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1. Executive Summary

This project, *Literature Review of the Nutritional and Health Benefits of Eggs,* was initially undertaken by Food & Nutrition Australia (FNA) on behalf of the Australian Egg Corporation Limited (AECL) between April-July 2004, and subsequently updated in November 2004, October 2005, January 2007, February 2009, May 2010, February 2012 and now in February 2013. The report provides a comprehensive overview of the nutritional profile of eggs, their role throughout the lifecycle and the latest scientific evidence regarding eggs and health.

Overall, eggs provide a broad range of nutrients and non-nutrients that play an important role in health and disease prevention. Nutritional highlights of eggs include their high quality protein and their provision of folate, selenium, iodine, long chain omega-3 fats, and the antioxidants lutein and zeaxanthin. These nutrients and non-nutrients offer benefits to people throughout the various stages of the human lifecycle. Identified in this report are the particularly useful roles eggs can play in the diets of children, vegetarians, pregnant women and older Australians.

In relation to egg intake and heart disease risk, the latest scientific evidence shows consumption of up to six eggs per week in a diet low in saturated fat is not associated with the risk of developing or dying from heart disease or stroke in the majority of the healthy population. Previous recommendations to restrict eggs in the diet as a strategy to reduce heart disease risk have now been reviewed by the National Heart Foundation of Australia and debate about the role of eggs in the diet for heart disease is continuing internationally. It is now well accepted that dietary cholesterol plays only a minor role in increasing blood cholesterol levels and that reducing saturated fat intake is significantly more effective as a strategy for reducing heart disease risk.

In relation to weight management, research suggests protein may have advantages over carbohydrate in relation to satiety. This effect means protein rich foods, such as eggs, may assist people in adhering to weight loss diets in the long term. This effect has been demonstrated in several studies and is likely to be an area for future research and development.

The growing body of evidence demonstrating benefits of a moderately higher protein, lower carbohydrate diet for weight loss is identified as an opportunity for the promotion of eggs as part of a weight reducing diet.

Egg allergy is reviewed and recommendations provided regarding the introduction of eggs into the diets of infants. For the majority of infants, egg yolks are considered a nutritious and beneficial weaning food that can be introduced from the age of 6-8 months. Some evidence is indicating early exposure to egg protein may have benefits for reducing future risk of allergy however further work is required before any change in recommendations in this area will occur. Recent emerging evidence is suggesting exposure to small amounts of egg protein may help build tolerance to egg in children with egg allergy faster than complete avoidance, however this practice is unlikely to transfer into clinical practice anytime soon.

Finally, government recommendations regarding the place of eggs in a healthy eating pattern, and in a diet for cholesterol reduction, are reviewed both nationally and internationally. While most heart related organisations do not specifically recommend limitations on egg intake, the majority recommend limitations for dietary cholesterol intake in people with existing elevated blood cholesterol levels. However most organisations acknowledge that restriction of dietary cholesterol is not as effective as reducing saturated fat for lowering heart disease risk.

Key communication messages are provided at the end of each section of the report and are summarized in section 2.

FNA would like to acknowledge that some of the information in this document has been developed as part of the work of the Egg Nutrition Council (ENC).

2. Summary - Key Communication Messages

The following messages are substantiated by the research reviewed and referenced in this report. Note that **these messages do not necessarily conform to the requirements of the Australia New Zealand Food Standards Code for direct use in advertising and marketing.** The messages may require wording changes depending on their usage within the AECL marketing and communications program.

Nutrient Content Messages

- Eggs provide the highest quality protein of all food sources, closely matching human requirements for essential amino acids.
- Eggs are an excellent source of protein with one serving providing one quarter of the recommended dietary intake for adults.
- Eggs are a good source of vitamin A and contain the right type of components to maximise absorption of this vitamin into the body. Vitamin A is needed for healthy skin and eyes and for a strong immune system.
- Older Australians and teenagers are more susceptible to low intakes of vitamin A. Eggs are a great choice for people in these age groups as they provide around 30% of the RDI for adults in one average serve, are easy to eat and quick to prepare.
- One serve of eggs provides a significant amount of vitamin A for children.
- Eggs are one of the few foods containing vitamin D. The vitamin D from eggs may be particularly well absorbed due the presence of fat.
- The elderly, children, adolescents, dark skinned, obese and veiled population sub-groups may particularly benefit from increased intakes of vitamin D rich foods, such as eggs.
- Many Australians, particularly older people, do not meet the RDI for vitamin E. Eggs provide a natural source of vitamin E with one serving contributing an average of 24% RDI.
- Eggs naturally provide a source of healthy fats that assist with increasing the absorption of vitamin E into the body.
- Eggs are a source of thiamin needed for conversion of carbohydrates into energy.
- Eggs are a good source of riboflavin needed for conversion of food into energy.
- One serve of eggs provides almost a third of the recommended dietary intake for riboflavin.
- Eggs are a rich source of vitamin B5 needed for conversion of food into energy.
- One serve of eggs provides over 40% of the recommended dietary intake for vitamin B5.
- Eggs are a good source of folate that is highly bioavailable.
- Eggs provide vitamin B12 along with folate, which can have advantages over folate-fortified foods.
- Including eggs regularly in the diet of pregnant women can make a significant contribution to meeting daily folate requirements, therefore promoting a healthy pregnancy.
- Eggs are an excellent source of vitamin B12 needed for healthy red blood cells.
- One serve of eggs provides almost half of the recommended dietary intake for vitamin B12.
- Eggs can be a particularly valuable inclusion in the diets of vegetarians as they provide vitamin B12, a nutrient often low in vegetarian diets.
- Eggs can be a particularly valuable inclusion in the diets of the elderly as requirements for vitamin B12 increase with ageing.
- Eggs provide a valuable source of iron for groups at risk of iron deficiency including vegetarians, toddlers, pregnant women and athletes.

- Eggs provide small amounts of zinc, which may be particularly useful in a vegetarian diet where animal sources of zinc are restricted.
- Eggs provide small amounts of zinc, which may be particularly useful in the diet of older Australians, as many do not meet recommended dietary intakes.
- Eggs are an excellent source of selenium, a trace mineral required for many functions in the body.
- Eggs are an excellent inclusion in a lower-carbohydrate eating pattern due to the presence of selenium, a powerful antioxidant that can be low when following this style of eating.
- Eggs are an excellent source of iodine.
- Eggs are one of the few natural sources of iodine.
- Eggs are one of only a few food sources of choline.
- Choline is particularly useful in the diet of pregnant and lactating women. Eggs are therefore highly recommended at this time of life.

Antioxidant Messages

- Eggs contain the antioxidants lutein and zeaxanthin. Increased intakes of these antioxidants have been associated with eye health and may provide protection against age related eye disease.
- Research indicates that high intakes of antioxidants from spinach, broccoli and eggs are associated with a reduced risk of cataract and age-related macular degeneration.
- The bioavailability of lutein and zeaxanthin is higher from eggs than from other plant sources.
- Eating around one egg a day results in increased antioxidant concentrations in the macular region of the eye. This in turn may be associated with protection from macular degeneration however further research is required to confirm this.
- Eggs contain the amino acids tyrosine and tryptophan which have antioxidant properties.
- Consuming eggs results in higher antioxidant levels in the body.

National Nutrition Survey Messages

- Australians continue to eat too much total fat and too much saturated fat and do not consume the recommended amounts of polyunsaturated fats.
- While there is no specific Australian recommendation for cholesterol intake, the average intake of cholesterol is within the recommended level of the American Heart Association, which states less than 300mg per day as ideal.
- The major contributors to saturated fat intake in the Australian diet are milk products and dishes, meat products and dishes and cereal based products and dishes. Eggs contribute comparatively little saturated fat to the average Australian diet.
- Eggs contribute a higher percentage of the healthy monounsaturated type of fat to the diet compared to the unhealthy saturated fats.
- The major contributors to cholesterol intake in the average Australian diet are meat, poultry and game products and dishes, milk products and dishes, and cereal based products and dishes. Eggs alone contribute only 11% of the average Australian intake of dietary cholesterol.
- Between 11-14% of Australian children (2-16 years) consume eggs or egg dishes each day.

Omega-3 Related Messages

- The average intake of omega-3 fats in Australia is well below the levels recommended for preventing chronic disease. Most Australians would benefit from increasing their intake of omega-3 fats.
- Eggs contain useful amounts of the long chain omega-3 fatty acids.
- Omega-3 fats provide heart health benefits and have anti-inflammatory properties.
- Including omega-3 enriched eggs in the diet improves omega-3 levels in the body, which in turn may have significant health benefits.
- Including omega-3 enriched eggs in the diets of infants may improve omega-3 status in the body, which in turn has significant developmental benefits.
- Vegetarian diets are relatively low in omega-3 fats. Due to their range of health benefits, ovo-vegetarians may particularly benefit from increasing food sources of omega-3 fats in their diet, such as eggs.
- Eggs are the only vegetarian source of the long chain omega-3 fatty acids DHA and DPA. They contain 114mg per serve, which represents71-127 % of the Adequate Intake (AI).
- Eggs are a valuable source of omega-3 fatty acids which are commonly lacking in the diets of Australian children.

Cholesterol, Cardiovascular Disease and Diabetes Messages

- Recent population studies show no, or very minor, associations between dietary cholesterol intake and risk of heart disease.
- Dietary cholesterol is not the main determinant of blood cholesterol levels.
- When cholesterol is taken in from food, the body balances the level in the blood by making less.
- Increasing dietary cholesterol intake results in a small increase in blood cholesterol levels. Of the small increase, around 25% is due to an increase in the 'good' HDL cholesterol level.
- People vary in their responses to increases in dietary cholesterol intake. A 100mg per day increase in dietary cholesterol can result in a three times greater effect on blood cholesterol levels in sensitive people compared to non-sensitive people.
- The effect of dietary cholesterol from eggs on blood cholesterol levels is even less if a person has a low saturated fat diet.
- Overweight people and those who are insulin resistant may be even less sensitive to changes in dietary cholesterol.
- The differences in individual responses to changes in dietary cholesterol intake may be due to genetics.
- Up to 85% of the population may be non-sensitive to changes in dietary cholesterol intake.
- In healthy individuals, most population studies have shown no association between levels of egg intake up to seven or more a day and increased risk of developing or dying from heart disease or stroke.
- Eating up to six eggs per week has little to no impact on the risk of heart disease in a healthy population.
- Research supports the inclusion of up to 6 eggs a week as part of a healthy diet for the management of diabetes.
- If there is a small increase in risk of heart disease through the addition of one egg a day, this increase in risk is non-significant when compared to the modification of other lifestyle related risk factors such as controlling body weight and reducing saturated fat intake.
- Up to 85% of the population produce less cholesterol when dietary cholesterol intake increases. This mechanism serves to regulate blood cholesterol levels.

- Including eggs in a weight-loss or carbohydrate-restricted diets does not increase LDL cholesterol, and has been shown to improve HDL cholesterol levels.
- Dietary cholesterol intake maintains the LDL:HDL ratio. The LDL:HDL ratio is a key marker of coronary heart disease risk.
- Dietary cholesterol intake alters the size of cholesterol particles in the body which may favourably effect heart disease risk.
- The current, best available evidence shows no association between egg consumption and risk of heart disease or stroke.

Eggs and Lifecycle Related Messages

- Eggs are an excellent way for pregnant women to meet their increased nutritional requirements during pregnancy. One serve of eggs provides almost 100% of the additional protein requirements and around a third of the extra kilojoules required during pregnancy and lactation. They also provide useful amounts of nutrients that assist in reaching the increased nutritional requirements of pregnancy such as iron, folate and zinc.
- Eggs can be a particularly useful inclusion in the diet of pregnant vegetarian women as they provide the ideal complement of all essential amino acids needed for growth and development.
- One serving of eggs provides over 30% the daily requirements for vitamin B12 during pregnancy.
- One serving of eggs provides 100% of the additional vitamin B12 requirements during pregnancy.
- Regular inclusion of omega-3 enriched eggs in the diet of breastfeeding mothers can significantly improve the omega-3 status of the infants. This in turn may have significant benefits for development of visual and brain function.
- Adequate vitamin D is important during pregnancy and lactation. Pregnant women may particularly benefit from increased intakes of foods containing vitamin D, such as eggs.
- Pregnant women are at risk of mild to moderate iodine deficiency. One serve of eggs provides 20% of the iodine RDI during pregnancy.
- Australian pregnant women often have low intakes of folate, iron and vitamin D. Eggs provide folate, iron and vitamin D and can therefore play a role in helping to meet these recommendations.
- Eggs are a nutritious food for children, fitting well within the Dietary Guidelines for Children and Adolescents.
- Eggs provide useful amounts of nutrients to improve the nutrient content of children's diets.
- One serve of eggs provides around a third of the recommended dietary intake of folate for children. Folate is essential for the growth and maintenance of healthy cells.
- One serve of eggs provides around half the recommended dietary intake of vitamin A for children. Vitamin A is essential for growth and eye health.
- Eggs provide a broad range of important nutrients essential to meet the needs of growing teenagers.
- Many teenagers fall short of vitamin A, folate, iodine, zinc, iron and phosphorus requirements. Eggs provide useful amounts of these nutrients and may help boost intakes closer to RDI levels.
- Due to the wide range of nutrients found in eggs, they are a particularly useful inclusion in the diet of teenagers who may be following special diets.
- Many teenagers skip breakfast and due to the variety of nutrients and protein found in eggs, they provide a nutritious start to a teenager's day.
- Eggs can play a significant role in a vegetarian diet due to the provision of high quality protein, vitamin B12 and iron, nutrients that are often low in a vegetarian eating pattern.

- Eggs can be a particularly valuable source of omega-3 fatty acids in a vegetarian diet as intakes are often particularly low in this group of people. Omega-3 fatty acids are essential for the health of the heart and blood vessels.
- One serve of eggs contains useful amounts of selenium (59% RDI), vitamin B12 (40% RDI) and iron (14% RDI), all nutrients that can be low in a vegetarian diet.
- Protein requirements are often higher than average for athletes and eggs provide a valuable source of high quality protein for this group.
- Eggs provide a range of valuable nutrients in the diets of sports people including iron, vitamin B12 and folate, all required for healthy red blood cells that carry oxygen to the working muscles.
- Eggs provide a range of valuable antioxidants, which may assist recovery after exercise by reducing muscle and cell damage.
- Evidence suggests sports people have increased antioxidant requirements. Eggs provide a range of antioxidant nutrients.
- Due to age related changes in the functioning of the digestive system, nutrient requirements can be higher in older Australians. Due to the variety of nutrients found in eggs, they can play a particularly valuable role in the diet of this group.
- The majority of older Australians do not meet the RDI for vitamins A and E and eggs can provide a useful contribution to meeting requirements with one serving providing 27-34% RDI for vitamin A and 24-34% RDI for vitamin E.
- Due to their soft texture, eggs may be a particularly suitable food in the diets of frail elderly.
- The incidence of heart related problems are highest in older Australians. Eggs are a source of omega-3 fatty acids, which have been shown to have benefits for the heart and blood vessels.
- Eggs contain the antioxidants lutein and zeaxanthin, which have been shown to be associated with lower rates of age-related macular degeneration (AMD). AMD is the leading cause of blindness in older Australians.

Eggs and Weight Related Messages

- Eggs fit well within a moderately higher protein, lower carbohydrate eating plan for weight loss. This style of eating may have particular benefits for certain groups within the population.
- Eggs are high in good quality protein. Protein has been shown to contribute to greater feelings of satisfaction after eating and may therefore help people to stick to a weight loss diet for longer.
- Muscle loss may be minimised when on a weight reduction diet by including higher amounts of protein rich foods, such as eggs, as part of the eating plan.
- Eggs fit well within a range of weight loss diets, providing significant amounts of vitamins, minerals and protein, while only contributing 581kJ per serve (2x60gram eggs).
- Eating eggs for breakfast as part of a low fat meal may assist in reducing food intake over the next 24 hours therefore helping weight management.
- Eating breakfast is associated with a lower body weight. Eggs are a healthy inclusion at breakfast with one serving (two eggs) providing around the same amount of kilojoules as 2 thin slices of toast.
- Eating eggs for breakfast can enhance weight loss when compared to eating a bagel based breakfast.
- When included as part of a low kilojoule or low carbohydrate diet, eggs do not increase blood cholesterol levels and in fact have been shown to lead to improvements in HDL levels.
- Eating eggs for lunch can help increase feelings of fullness and may help reduce snacking in the afternoon.

- Protein diets containing an average of 27% energy as protein may assist in weight management and also have beneficial effects on blood pressure and triglyceride levels.
- Consuming eggs for breakfast increases satiety and results in lower energy intake during the remainder of the day compared with a cereal or croissant breakfast.

Eggs and Food Allergy Messages

- Egg allergy is one of the most common allergies in children, affecting up to 8.9% of children.
- Approximately 85% of children will grow out of their egg allergy.
- Parents with egg allergy should be particularly careful to avoid the presence of eggs around their infants in order to minimize sensitization via the inhalation route.
- People with an allergy to egg should avoid all types of eggs, including duck, goose and quail.
- Healthy infants with no family history of egg allergy may eat egg yolk from 6-8 months of age.

3. Key Nutrients in Eggs and Their Role in Health

Eggs are a valuable source of a broad range of nutrients and are therefore a useful inclusion in a healthy eating pattern. This section provides an overview of the nutritional roles and dietary requirements for the key vitamins and minerals found in eggs and where relevant and appropriate, highlights the benefits of obtaining these nutrients from eggs.

Example communication messages are highlighted at the end of each section. Where nutrient claims are included, such as source of vitamin or mineral claims, these are worded to be consistent with the requirements of the Australia New Zealand Food Standards Code (Standard 1.3.2) (as at February 2013) as follows:

- To make a claim that a food is a source of a vitamin or mineral, one reference quantity (one average serving) must provide at least 10% of the recommended dietary intake (RDI);

- To make a claim that a food is a good source of a vitamin or mineral, or words to that effect, a reference quantity (one average serving) must contain at least 25% of the RDI for that vitamin or mineral.

The Food Standards Code (Standard 1.1.1) sets out RDIs for labelling purposes [1]. These figures are used in Section 3 of the report when referring to messages regarding percentages of the RDI provided by a serving of eggs unless specified (for instance children, pregnant women and the elderly, whose RDIs have been calculated using the 2006 NHMRC Nutrient Reference Values [2]). Note the labelling figures are currently under review by FSANZ to bring them in line with the Nutrient Reference Values. Figures are therefore likely to change over the coming years. The Food Standards Code (Standard 1.2.8) also sets out values for percentage daily intakes for energy, protein, fat, saturated fat, carbohydrate, sodium, sugars anddietary fibre. These values are used at various places in this report.

Notes:

1. *Throughout this report, one serve of eggs refers to two 60 gram eggs (edible weight from excluding the shell is 104grams).*
2. *Key messages are not necessarily worded to meet the requirements of the Australia New Zealand Food Standards Code regarding prohibition of health claims in advertising and labelling. It is therefore recommended that all messages be reviewed by FNA and/or AECL's legal advisers prior to use in marketing and advertising.*

3.1 Nutrient Profile of Whole Raw Australian Hen Eggs and % Recommended Dietary Intake (RDI) for Key Nutrients

Nutrients	RDI*	Per 100g	Per serve			
			2x52g eggs (90g edible portion)	**2x60g eggs** (104g edible portion)		**2x68g eggs** (118g edible portion)
					%RDI	
Energy (kJ)	8,700	559	503	581	7%	660
Protein (g)	50	12.2	11.0	12.7	25%	14.4
Fat (g)	70	9.9	8.9	10.3	15%	11.7
Sat fat (g)	24	3.3	3.0	3.4	14%	3.9
Mono fat (g)	n/a	5.1	4.6	5.3	n/a	6.0
Poly fat (g)	n/a	1.6	1.4	1.7	n/a	1.9
Cholesterol (mg)	n/a	383	345	398	n/a	452
Carbohydrate (g)	310	1.3	1.2	1.4	0%	1.5
Sugars (g)	90	0.3	0.3	0.3	0%	0.4
Sodium (mg)	2300	136	122	141	6%	160
Potassium (mg)	2800 (f), 3800 (m)^	133	120	138	4-5%	157
Magnesium (mg)	320	12	11	13	4%	14
Calcium (mg)	800	47	42	49	6%	55
Phosphorus (mg)	1000	200	180	208	21%	236
Iron (mg)	12	1.6	1.4	1.7	14%	1.9
Selenium (µg)	70	39	35	41	59%	46
Zinc (mg)	12	0.5	0.5	0.5	4%	0.6
Iodine (µg)	150	41	37	43	29%	48
Thiamin (Vitamin B1) (mg)	1.1	0.12	0.11	0.12	11%	0.14
Riboflavin (Vitamin B2) (mg)	1.7	0.5	0.5	0.5	29%	0.6
Niacin (mg)	10	<0.01~	<0.01~	<0.01~	n/a	<0.01~
Vitamin B6 (mg)	1.6	0.05	0.05	0.05	3%	0.06
Vitamin B12 (µg)	2	0.8	0.7	0.8	40%	0.9
Pantothenic acid (vitamin B5) (mg)	5	2	1.8	2.1	42%	2.4
Folate (µg)	200	93	84	97	49%	110
Vitamin A (Retinol) (µg)	750	230	207	239	32%	271
Vitamin D (Cholecalciferol) (µg)	10	0.8	0.7	0.8	8%	0.9
Vitamin E (Alpha-tocopherol) (mg)	10	2.3	2.1	2.4	24%	2.7
Omega - 3 fatty acids (total) (g)	0.89 (f), 1.46 (m)^	0.17	0.15	0.18	12-20%	0.20
Short chain Omega-3s (ALA) (g)	0.8 (f), 1.3 (m)^	0.06	0.05	0.06	5-8%	0.07
Long chain Omega-3s (DHA/DPA) (mg)	90 (f), 160 (m)^	110	99	114	71-127%	130
Omega-6 fatty acids (g)	8 (f), 13 (m)^	1.37	1.23	1.42	11-18%	1.62
Choline						
Lutein (mg)	n/a	0.38	0.34	0.40	n/a	0.45
Zeaxanthin (mg)	n/a	0.13	0.12	0.14	n/a	0.15
Lutein + zeaxanthin (mg)	n/a	0.51	0.46	0.53	n/a	0.60
Biotin (µg)	30	<8~	<8~	<8~	n/a	<8~
Fluoride (mg)	3 (f), 4 (m)^	<1~	<1~	<1~	n/a	<1~
Chromium (mg)	0.2	<0.01~	<0.01~	<0.01~	n/a	<0.01~
Copper (mg)	3	<0.02~	<0.02~	<0.02~	n/a	<0.02~
Manganese (mg)	5	0.023	0.021	0.024	0%	0.027
Molybdenum (mg)	0.25	0.012	0.011	0.012	5%	0.014
Vitamin K (µg)	80	<2~	<2~	<2~	n/a	<2~

* Food Standards Australia New Zealand Food Standards Code. Reference Values for Recommended Dietary Intakes on Food Labels, Standard 1.1.1, Schedule Column 3 and Daily Intakes, Standard 1.2.8, Table to subclause 7(3)
^ National Health and Medical Research Council. Nutrient Reference Values for Australia and New Zealand, 2006. Adequate Intakes (AI) ~ Limit of Quantification

3.2 Protein

Protein is required daily in the diet for the following reasons:

- To provide the building material for synthesis of cells and tissues
- As a component of all enzymes and hormones
- To build contractile protein in muscle, enabling muscle contraction and movement
- To form antibodies needed as a component of a strong immune system

There are 20 amino acids that the body requires in order to build all of the proteins required for health and normal functioning of the body. Of these, there are 9 that have to be provided preformed in the diet and these are called the 'essential' or 'indispensable' amino acids.

The recommended dietary intake (RDI) for protein is [2]:

Children 1-3 years	14grams
Children 4-8 years	20grams
Boys 9-13 years	40grams
Girls 9-13 years	35grams
Boys 14-18 years	65grams
Girls 14-18 years	45grams
Men 19-70 years	64grams
Women 19-70 years	46grams
Men 70+ years	81grams
Women 70+ years	57grams

The Daily Intake (DI) value for protein used for labelling purposes is 50grams [3].

Sources

Sources of protein in the diet are extensive and include meat products, dairy, eggs, nuts, legumes and soy products. While animal sources of protein provide a good balance of essential amino acids, most plant sources do not. It is therefore recommended that vegetarians who eat no animal protein foods consume a mixture of different plant sources of protein to ensure sufficient quantities of all amino acids are obtained from the diet.

Protein quality is measured by considering how closely the ratio of amino acids in the food protein matches human requirements. If a food protein is rich in essential amino acids, and the relative amounts closely match human requirements, the protein will have a high nutritional quality. This is the case for proteins found in eggs, milk or meat [4]. Hen's eggs are considered to have the highest nutritional quality protein of all food sources, providing all the essential amino acids in amounts that closely match human requirements [5]. Egg protein is the nutritional standard against which all other proteins are compared [6]. Both the biological protein value and digestibility of egg protein contributes to the remarkable nutritional quality of eggs [7]. Greater than 95% of egg protein is digestible, meaning eggs are classified as a highly digestible protein source [7].

Amount in eggs

One serve of eggs provides 12.7grams of protein. This represents 25% of the DI for adults.

People who might benefit from increased protein intakes

As protein is present in so many foods, most people meet protein requirements easily. The average Australian intake is 91.2 grams daily [8], well above RDI levels. Additionally, the 2007 Children's Nutrition and Physical Activity Survey showed children in all age groups exceeded the RDIs for protein, with average intakes found to be two to four times higher than recommendations [9]. However, there are certain groups within the population that may benefit from increased intakes or higher quality sources, including ovo-vegetarians, children and adolescents, elderly people and those participating in regular resistance training.

- Ovo-vegetarians may have a limited intake of essential amino acids by making poor food choices, due to the smaller variety of protein containing foods eaten. This in turn can result in an insufficient intake of essential amino acids [7]. Additionally, the protein digestibility and lower biological protein value of many plant proteins may result in deficient dietary intakes of essential amino acids in ovo-vegetarian diets [7]. The total protein content of a vegetarian diet is significantly lower than an omnivore diet [10]. Due to their high protein quality and high digestibility, eggs may therefore be particularly useful in the diets of ovo-vegetarians [7].
- Children and adolescents have increased requirements for protein during periods of growth [11]. Evidence also shows that higher protein, low glycemic load diets can improve symptoms of acne that is common in teenagers [12,13]. Eggs are an excellent source of protein for children and adolescents due to their ideal amino acid profile, nutrient density and versatility.
- Elderly people aged 70 years and over have a greater RDI for protein than younger people, and may need additional protein intake to stimulate muscle protein formation [14]. It has been demonstrated that the formation of muscle protein in the elderly can be stimulated by the increased availability of protein and/or amino acids from foods [15]. This suggests that maintaining adequate dietary intake of protein can help address muscle wasting. Increasing protein intake may also assist wound healing in the elderly [6]. Eggs are an ideal protein source for the elderly as they are economical, easy to prepare and easy to chew.
- Certain athletes who undergo resistance training, particularly in the early phases of their program where muscle synthesis is high, can benefit from extra dietary protein [16]. Eggs are a highly bioavailable protein source that can easily be included in the diets of athletes without adding unwanted bulk. A study has shown that 20g of ingested protein after resistance exercise had a positive effect on muscle building in young men [17]
- People following a kilojoule-controlled diet may benefit from an increased percentage of energy from protein. A growing body of evidence, including a number of Australian clinical trials, have demonstrated that moderately higher protein, lower carbohydrate, kilojoule controlled diets provide an effective weight loss strategy for some [18-23]. Higher protein may help with weight loss due to its satiating effect and correlating suppressing of energy intake[24]. Being nutrient dense and a good source of high quality protein, eggs are one food that fit well within the dietary recommendations for moderately higher protein weight loss diets.
- Higher protein intakes (15% and 25% vs 5%) have also been shown to increase energy expenditure and lean body mass[25]
- A 2012 study also showed a benefit of 25% energy from protein compared to 15% energy from protein on lowering blood pressure in overweight adults with high blood pressure[26]. Similarly, a meta-analysis of 40 randomised controlled trials[27] found that compared with carbohydrate, dietary protein intake was associated with significant reductions in mean systolic and diastolic blood pressure. Both vegetable protein and animal protein were associated with a significant reduction in blood pressure.

- People at risk of heart disease may also benefit from higher protein intakes with an association study of 2537 adults finding higher dietary protein intake was associated with enhanced HDL-C levels, lower waist circumference, and lower diastolic BP, and a higher ratio of animal/plant protein intake was related with lower serum fasting glucose and waist circumference[28]. Furthermore, a review concluded that higher protein diets probably improve adiposity (including weight loss and BMI), blood pressure and triglyceride levels[29].
- Intake of protein (total and animal but not vegetable) has also been associated with a decreased risk of stroke and cerebral infarction in women[30]

Advantages of protein from eggs
The protein in eggs is highly bioavailable, and of the highest nutritional quality compared to all other food sources [7].

Example communication messages:
- Eggs provide the highest quality protein of all food sources, closely matching human requirements for essential amino acids.
- Eggs are an excellent source of protein with one serving providing 25% of the recommended dietary intake for adults and 20-36% for children over 9.

3.3 Fats

Fat is required daily in the diet for the following functions:
- Major source of energy (kilojoules)
- Key component of cell membranes
- Hormone synthesis
- Absorption of fat soluble vitamins

Recommendations for fat intake for good health are that no more than 20-35% of total energy should come from fat, with saturated fat providing less than 10% of total energy [2]. For children over 2 years, the same recommendations apply. Children under 2 years of age require more fat, with the Australian Dietary Guidelines for Children and Adolescents recommending that 40% of the energy of children's diets in the latter part of the first year and during the second year of life come from fat [11]. See Section 6 for specific omega-3 and omega-6 fatty acid recommendations.

The Daily Intake (DI) value for fat used for labelling purposes is 70grams, and 24grams for saturated fat [3].

Sources
Fat is found in a wide variety of foods including meat and dairy products, eggs, oils, full cream dairy products, butter and margarine, nuts, fast foods and snack foods. The major sources of saturated fat in the Australian diet are outlined in section 5, table 3.

Amount in eggs
One serve of eggs provides 10.3grams of total fat. Of this, 3.4g is saturated, 5.3g is monounsaturated and 1.7g is polyunsaturated. Eggs also provide omega-3 fatty acids, contributing an average of 180mg per serve. Of this, 114mg is the long chain omega-3 fatty acids DHA and DPA, which represents 71-127% of the adequate intake (AI) [2]. Eggs enriched with omega-3 fatty acids provide even more of these fatty acids. For instance, the Body Egg available in Australia contains 1113mg total omega-3 (905mg ALA and 208mg long chain EPA/DHA) per serve. Note however that amounts vary between brands.

Results from the National Nutrition Survey [8] show egg products and dishes contribute 2% of the average total fat intake, 1.6% of the average total saturated fat intake, 1.7% of the average total polyunsaturated fat intake and 2.5% of the average total monounsaturated fat intake in the Australian diet. Egg products and dishes therefore make a greater contribution to unsaturated fat intakes in the average Australian diet and contribute relatively little to saturated fat intakes.

People who might benefit from changing their intake of fat

- Infants and young children require fats for energy during growth. As total food consumption is small due to their smaller stomach capacity, fats provide a vital source of energy.
- People who overly restrict their fat intake and follow excessively low fat diets, limiting intakes of essential fatty acids and fat soluble vitamins e.g. dieters.
- The most recent recommendations from the National Heart Foundation of Australia on dietary fat focus on reducing saturated fat and trans fat in the diet rather than total fat as a priority[31]. It is recommended that saturated fat is replaced with polyunsaturated and monounsaturated fat.
- Most Australians consume too much saturated fat and reducing saturated fat intake is a focus for improving the general health of the population.
- Most Australians do not meet the intakes recommended for omega-3 fats for prevention of disease and need to increase foods rich in these types of fat for optimal health. The Heart Foundation recommends the consumption of 500mg of omega 3 EPA plus DHA and the consumption of 2g omega 3 ALA daily[31].

Advantages of fat from eggs

- Fat in eggs assists absorption of the fat soluble vitamins (A, D and E) present within the egg.
- 68% of the fat in eggs is the healthy monounsaturated and polyunsaturated types.

Example communication messages:

- *Refer to sections 6 and 7 of this report.*

3.4 Vitamin A

Vitamin A is required in the body to carry out the following functions [5]:

- Interacts with genetic material to regulate growth, repair and cell differentiation
- Required for healthy skin and eyes (protects against night blindness)
- Provides resistance to infection by maintaining healthy mucous membranes
- Acts as an antioxidant

The recommended dietary intake (RDI) for vitamin A is [2]:

Children 1-3 years	300µg RE*
Children 4-8 years	400µg RE
Children 9-13 years	600µg RE
Boys 14-18 years	900µg RE
Girls 14-18 years	700µg RE
Adult women	700µg RE
Adult men	900µg RE
Pregnant women	800µg RE
Lactating women	1100µg RE

***** *RE = retinol equivalents*

The RDI currently used for labelling purposes is 750µg RE [1].

Vitamin A is found in two forms in the diet – preformed vitamin A (retinol) and provitamin A (beta-carotene). In Western countries such as Australia, the predominant source of vitamin A is from preformed vitamin A in animal products such as liver, oily fish, cream, full cream milk, cheese, butter and egg yolk [5].

Amount in eggs
One serve of eggs provides 239µg of vitamin A as retinol. This represents 32% of the RDI for adults.

People who may benefit from increased intakes of vitamin A

- The 1995 National Nutrition Survey reported that all groups of the population met vitamin A requirements. However, research conducted at the University of Melbourne and published in 2002 shows the average intake of vitamin A in older Australians is below the RDI [32]. In addition, the 2007 Children's Survey showed 21% of males and 14% of females aged 14-16 years were found to consume less than the Estimated Average Requirement (EAR) for vitamin A [9].
- Lower than recommended intakes of vitamin A in older people can lead to dry skin, poor vision, lowered immunity, and may contribute to diseases such as cancer [5]. The Victorian study referred to above found 56% of men aged 44 years and over and 68% of women in this age bracket had vitamin A intakes less than the RDI [32]. Due to fragility of the skin with age, and chronic diseases such as diabetes, elderly people are more susceptible to skin disturbances such as ulcers. Vitamin A is an essential nutrient in wound healing. Reduced digestive function also occurs with old age, which can reduce vitamin A absorption.
- Infants and children are more susceptible to suboptimal intakes of vitamin A due to a lower variety of foods eaten. Vitamin A is essential during the early years for growth, and healthy functioning of the eyes, skin and mucous membranes [5]. Children who do not eat yellow/orange fruit and vegetables or have sufficient dairy products daily are at increased risk of low vitamin A intakes.
- Exercise produces free radicals that can damage cell membranes. Vitamin A is an antioxidant that may protect cells in athletes who undertake strenuous exercise [33].

Advantages of Vitamin A from eggs
Vitamin A is a fat soluble vitamin meaning it requires fat for absorption. Eggs contain fat and therefore naturally provide optimal conditions for maximum absorption. Eggs are a nutritious and easy inclusion in children's diets and can offer an alternative source of Vitamin A to fruit and vegetables, with one serve providing 80% of the RDI for children aged 1-3, and 40-60% of the RDI for older children [2].

Example communication messages:

- Eggs are a good source of vitamin A and contain the right type of components to maximise absorption of this vitamin into the body. Vitamin A is needed for healthy skin and eyes and for a strong immune system.
- Older Australians and teenagers are more susceptible to low intakes of vitamin A. Eggs are a great choice for people in these age groups as they provide around 30% of the RDI for adults in one average serve, are easy to eat and quick to prepare.
- One serve of eggs provides a significant amount of vitamin A for children.

3.5 Vitamin D

Vitamin D is required in the body to carry out the following functions [34]:

- Enhancement of calcium and phosphorus absorption
- Development and maintenance of healthy bones and teeth
- Development and maintenance of a healthy nervous and immune system
- Regulation of certain hormones

The Adequate Intake (AI) values for vitamin D are [2]:

Children, adults 19-50 years	5μg
Adults 51-70 years	10μg
Adults 70+ years	15μg

The RDI currently used for labelling purposes is 10μg [1].

A working party, made-up of members from Australia and New Zealand, released a position statement for vitamin D in 2005 [34]. Both this working party and the National Health and Medical Research Council recommend the following:

- Pregnant women and young children receive reasonable summer sunlight exposure
- For those who are house-bound, or not exposed to direct sunlight for at least 1-2 hours per week, a daily oral intake of 400 IU (10 μg) vitamin D is recommended
- Diets of the elderly should include food sources of vitamin D.

Sources

Vitamin D is found in fatty fish such as mackerel and herring, liver, egg yolk, and foods fortified with vitamin D [34]. During processing, vitamin D can be added to margarines, butter, milk and some breakfast cereals. Mushrooms grown under light also contain significant Vitamin D. Vitamin D can also be obtained through the action of sunshine on the skin which converts an inactive form of vitamin D to the active form [34].

Amount in eggs

One serve of eggs provides 8% of the AI for vitamin D. Eggs are one of the few foods that naturally contain vitamin D. Two eggs provide twenty times as much vitamin D as an average glass of full cream milk and thirty times as much as a glass of reduced fat milk [35].

Data presented by FSANZ (Heather Greenfiled) at the NSA Conference 2012 showed eggs (n=16) ranged in vitamin D content from from 0.5 – 2.9ug/100g vitamin D3 and for 25OHD3 was 0-4.2ug/100g. These eggs were tested at Sydney University using the HPLC method. The presenter suggested some of the values seen in the eggs were due to 25OHD3 being used in the feed. These results are in the pipeline to be published. Nutrient testing to be conducted by AECL in 2013 will be valuable in confirming these numbers.

People who may benefit from increased intakes of vitamin D

- Recent national figures suggest 22% of men and 39% of women in Australia are vitamin D deficient[36]. NSW figures from patient records show higher rates of deficiency[37]. During summer, 36% of subjects had a deficient level, increasing to 58% in spring.
- 48% of daily vitamin D intake in Australia is derived from margarine. People who do not consume margarine are likely to benefit from other food sources of vitamin D [38], such as eggs.

- Vitamin D deficiency is particularly high in elderly, dark skinned and veiled population sub-groups [38]. Other factors associated with vitamin D deficiency identified in a 2012 study[37] included being tested in spring, being a hospital patient, female, aged 20-39 or over 79 years, socioeconomically disadvantaged and from a major city.
- The elderly don't convert vitamin D through the skin as effectively as younger people [2].Reseach has shown that elderly people with the lowest levels of vitamin D were four times more likely to have impaired brain function than those with the highest levels [39]A recent review found that middle aged and elderly people with high blood levels of vitamin D may be at a 33 per cent lower risk of developing heart disease [40]
- Vitamin D is also generally lower in people who have obesity. Circulating vitamin D levels have been found to increase with weight loss in women who are overweight or obese. This is because vitamin D is stored in fat deposits and with weight loss the nutrient is released from the stores into the blood[41]. A 2012 study has also suggested that low vitamin D levels may predispose women to fat accumulation since women with higher vitamin D levels gained less weight over time than women with lower levels
- In 2011, the Royal Australian and New Zealand College of Obstetrics and Gynaecology released guidelines recommending all obese pregnant women should be screened for vitamin D deficiency[42]. A review[43] of the importance of vitamin D in pregnancy and lactation has outlined research findings that show the following potential benefits of vitamin D: maintenance of immune system of both mother and fetus, protection against impaired fetal growth and other adverse outcomes such as preeclampsia, bacterial vaginosis; decreased likelihood of ceaseran delivery. (Mainly association studies). A 2012 systematic review also found low vitamin D levels were associated with adverse fertility parameters, preeclampsia, gestational diabetes or higher blood glucose, bacterial vaginosis, primary cesarean section, none or a few days' shorter gestation and post partum depression[44]. Similarly a systematic review and meta-analysis concluded that low maternal vitamin D levels in pregnancy may be associated with an increased risk of preeclampsia, gestational diabetes mellitus, preterm birth and small-for-gestational age[45]. In addition, a 2012 cohort study of 977 women has found lower vitamin D levels in pregnancy is associated with lower fat mass at birth but higher fat mass at ages 4 and 6 [46] and a study of 1820 Spanish mothers has found higher levels of vitamin D in pregnancy were associated with improved mental and psychomotor development in 14 month old infants[47].
- In addition to high risk groups, research shows children and adolescents have low dietary intake of vitamin D [9] and could therefore benefit from increasing intakes of vitamin D from foods they readily consume.A study has found children who get their daily dose of Vitamin D have a reduced risk of developing Type 1 diabetes.[48]Furthermore a recent study has linked vitamin D deficiency with increased risk of food allergy in children with a certain genetic make-up (IL 4 gene polymorphism)[49].
- A recent US study has shown intakes of vitamin D from food sources has decreased over time[50].
- Teenage girls in particular showed improved muscle function with higher levels of vitamin D ([51]).
- Studies have shown vitamin D deficiency may increase the risk of heart disease with low levels associated with high blood pressure, obesity, metabolic syndrome, diabetes, stroke and heart failure [52]
- Sub-optimal vitamin D has also been associated with prostate cancer [53] vaginal infections [54] and dementia [55]
- A study in young women aged 16-22 found insufficient levels of vitamin D in the blood may be associated with the accumulation of fat in muscle tissue, leading to lower muscle strength.[56]

- A study showed that vitamin D deficiency may put women at higher risk of incontinence and pelvic floor disorders. Results showed that women with below normal levels of vitamin D were more likely to have incontinence and one or more pelvic floor disorders irrespective of age [57]
- Vitamin D may improve the immune function of pregnant women and protect the placenta from infection [58]Results from a study presented at the American Academy of Neurology 62nd Annual Meeting in Toronto showed that the risk of multiple sclerosis was lower among women whose mothers had a high intake of either vitamin D or milk during pregnancy.

- A study suggested that higher levels of vitamin D may double survival rates of those with bowel cancer [59]
- A recent study has linked highintakes of vitamin D from food with lower rates of self-reported depressive symptoms[60].
- Two studies have linked vitamin D with type 2 diabetes. The first study[61] showed daily supplementation with vitamin D reduced markers of type 2 diabetes in an at risk population. The second study[62] found people who developed diabetes had lower levels of vitamin D in their blood compared to those who did not develop diabetes.
- Low vitamin D status has been linked to reduced cognitive function, particularly in women[63]
- A study has found that kids who are deficient in vitamin D accumulate fat around the waist and gain weight more rapidly than those who get enough vitamin D[64]. Vitamin D deficiency was also linked to slower growth in height among girls but not boys[64].
- A study has found that men and women over the age of 65 have increased risk of depressive symptoms if they have low vitamin D levels, with the association stronger in women than in men[65].
- A study has found that higher vitamin D status was associated with decreased risk of type 2 diabetes and that maintaining optimal vitamin D status may be a strategy to prevent the development of type 2 diabetes[66].
- Results of a new study presented at The Endocrine Society's 91st Annual Meeting in Washington, found that Vitamin D levels in the body at the start of a low-calorie diet may predict weight loss success. Those who had higher levels of vitamin D before the diet had more weight loss success than those with lower levels.
- A study showed that increased intakes of vitamin D may reduce the incidence of seasonal flu[67].
- Results of a study suggest that higher vitamin D status is associated with decreased risk of type 2 diabetes mellitus[68]
- Higher vitamin D levels may protect against childhood asthma[69].
- The elderly – higher blood levels of vitamin D associated with better physical function[70].
- A study of patients with inflammatory diseases of the spinal cord has found that the vitamin D levels are significantly lower in patients who developed recurrent spinal cord disease[71].
- The data from one study suggests a nonlinear decrease in mortality risk as circulating vitamin D levels increase, with optimal concentrations around 75–87.5 nmol/L[72].
- Vitamin D has been shown to be inversely associated with stress fracture risk[73]
- Low vitamin D during pregnancy has been linked with offspring language impairment [74]
- An association study has suggested that low vitamin D intake increases the risk of stroke in men[75].

- Higher blood levels of vitamin D have also been associated with a decreased risk of diabetes[76]. This finding has been confirmed in a meta-analysis of 16 studies[77]. Vitamin D deficiency is regarded as a potential risk factor for type 2 diabetes, however the vast majority of this research supporting this is of observational nature. Randomised controlled trials are needed to confirm this link[78,79].
- A review and meta-analysis has found a significant, but weak, inverse association found between vitamin D levels and BMI[80].

NOTE: A note about the evidence for vitamin D health effects: the majority of evidence linking vitamin D levels with health outcomes are association (observational) studies which do not prove cause and effect. There remains the possibility that vitamin D status is a marker of overall health and wellbeing and that the health effects seen in the studies are not directly attributable solely to vitamin D status.

Advantages of vitamin D from eggs
Vitamin D is a fat-soluble vitamin, and eggs contain the fat needed for absorption. Eggs are easy to prepare, economical and can be a regular part of the diet. They are also easy to eat, which is beneficial for elderly who often have poor dentition. The vitamin D content of eggs can be safely increased by feeding hens vitamin D3 rich diets[81,82]. The preservation of vitamin D3 and 25-hydroxyvitamin D3 in egg yolk after cooking is high and only modestly affected by storage, with losses of <10% in both cases A study in Irish pregnant women has found eggs to be one of the main dietary contributors to vitamin D intake[83]

Example communication messages:
- Eggs are one of the few foods naturally containing vitamin D. The vitamin D from eggs may be particularly well absorbed due the presence of fat.
- The elderly, children, adolescents, dark skinned, obese and veiled population sub-groups may particularly benefit from increased intakes of vitamin D rich foods, such as eggs.
- Adequate vitamin D is important during pregnancy and lactation. Pregnant women may particularly benefit from increased intakes of foods containing vitamin D, such as eggs.

3.6 Vitamin E

Vitamin E is required in the body to carry out the following functions:
- Antioxidant activity
- Maintenance of cell membranes
- Maintain healthy red blood cells and nerves
- Anti-inflammatory effect
- Stimulation of the immune response

The Adequate Intake (AI) for vitamin E is [2]:

Children 1-3 years	5mg
Children 4-8 years	6mg
Boys 9-13 years	9mg
Girls 9-13 years	8mg
Boys 14-18 years	10mg
Girls 14-18 years	8mg
Men	10mg
Women	7mg
Lactation	11mg

The RDI currently used for labelling purposes is 10mg [1].

Sources
Vitamin E is found in a variety of foods including eggs, wheat germ oil, sunflower seeds/oil, peanut oil, olive oil, margarine, almonds, peanut butter, whole grains, fish and some vegetables.

Amount in eggs
One serve of eggs provides 2.4mg of vitamin E, which is 24% of the RDI. Vitamin E enriched eggs, such as the Body Egg, can provide significantly more vitamin E in one serve (151% RDI).

People who may benefit from increased intake of vitamin E

- There is limited data on the vitamin E intake of the Australian population, with true deficiency being rare. However a 2002 study of older people in Victoria showed 92% of males and 80% of females aged 44 years and over have vitamin E intakes less than the RDI [32]. Absorption of vitamin E is also likely to be reduced in elderly people. A 2010 Australian study of free-living elderly women aged 70-85 years found that this group of subjects had suboptimal vitamin E intakes[84].
- A 2004 US study [85] showed intakes of vitamin E are low with only 8% of men and 2.4% of women meeting the estimated average requirements for this vitamin. Foods high in vitamin E are also generally high in fat and these foods have been reduced in the diets of many people in order to follow a low fat eating pattern. This American study identified that increasing intakes of nuts, seeds and vitamin E rich oils would improve vitamin E status [85].
- The 2007 Children's Survey showed children and teenagers consume less than the AI for vitamin E, but this may be because of a lack of data on the vitamin E content of the Australian food supply [9].
- Current research is investigating whether vitamin E may play a role in the prevention of heart disease, but studies have yielded mixed results.

Advantages of vitamin E from eggs
As vitamin E is a fat-soluble vitamin it requires fat for absorption and fat is naturally provided in eggs. Fortified eggs can also provide more than the RDI in one serve.

Example communication messages:

- Many Australians, particularly older people, do not meet the RDI for vitamin E. Eggs provide a natural source of vitamin E with one serving contributing 24% of the RDI.
- Eggs naturally provide a source of healthy fats that assist with increasing the absorption of vitamin E into the body.

3.7 Folate

Folate is required in the body for the following functions:

- Works in combination with vitamin B12 to protect and develop the nervous system
- Production of genetic material
- Needed for production of red blood cells
- Needed for a healthy pregnancy - helps prevent spina bifida

The recommended dietary intake (RDI) for folate is [2]:

Children 1-3 years	150µg
Children 4-8 years	200µg
Children 9-13 years	300µg
Adolescents 14-18 years	400µg
Adults	400µg
Pregnant women	600µg
Lactation	500µg

The RDI currently used for labelling purposes is 200µg [1].

Sources

Sources of folate include eggs, yeast extracts (Vegemite, Marmite), green leafy vegetables, peas, legumes, whole grains, nuts, avocadoes and organ meats (liver, kidney, heart). Folate is also added to certain foods such as breakfast cereals, bread and fruit juice.

Amount in eggs

One serve of eggs provides 97micrograms of folate, which is 49% of the RDI for adults. Folate enriched eggs, such as the Body Egg, provide 52% RDI.

People who may benefit from increased intakes of folate

- Pregnant women and women of childbearing age have greater requirements for folate with government recommendations being that all women falling into these groups take a daily folate supplement [86]. Folate in pregnancy is necessary for normal foetal spine, brain and skull development[87]. In particular, adequate folate prevents neural tube defects from developing.
- As the formation of healthy red and white blood cells requires folate, athletes may have higher requirements.
- Folate can reduce the level of homocysteine in the blood, a known risk factor for coronary artery disease. Individuals who have cardiovascular disease or are at increased risk may benefit from increased folate intakes. The National Heart Foundation of Australia has identified homocysteine as a risk factor for heart disease and recommends that people with vascular disease take folate supplements [88]. The updated Nutrient Reference Values also suggest that an additional 100–400 micrograms of folate per day may be required to optimise homocysteine levels and reduce overall chronic disease risk and DNA damage [2].
- An analysis of 14 studies showed a significant relationship between the highest intake of folate and a reduced risk of heart disease[89]. An increase of 200ug folate per day was associated with a 12% decreased risk.
- One study has shown that those with the lowest folate levels were 30% more likely to have an allergy and 16% more likely to have asthma than those with the highest levels [90]
- Age-related hearing loss may arise in part due to folate deficiency. Elderly patients with hearing loss had blood folate levels that were 32% lower than those of similar-age patients with normal hearing[91] . Elderly people, in general, may be at risk of folate deficiency with one Australian study showing suboptimal folate intake in free-living elderly women (aged 70-85 years)[84].
- Folate and vitamin B6 levels are inversely associated with mortality from heart failure[92].
- Lower intakes of B vitamins including folate have been linked to poorer mental health in adolescents[93].

Advantages of folate from eggs

Research presented at the 2004 Egg Nutrition for Health Promotion conference found folate bioavailability is greater from eggs compared to cereals and folate supplements [94]. This is advantageous as eggs also contain vitamin B12, which works synergistically with folate. Criticisms of folate fortification of the food supply are that folate can mask vitamin B12 deficiency [94]. Eggs have an advantage over folate-fortified foods such as breakfast cereals as they provide both of these vitamins. A study has also shown that the consumption of eggs or spinach both produced a significant increase in plasma folate concentrations thirty minutes after eating, while for yeast extract this increase in plasma folate was seen after one hour [95].

Example communication messages:

- Eggs are a good source of folate that is highly bioavailable.
- Eggs provide vitamin B12 along with folate, which can have advantages over folate-fortified foods.
- Including eggs regularly in the diet of pregnant women can make a significant contribution to meeting daily folate requirements, therefore promoting a healthy pregnancy.

3.8 Thiamin

Thiamin is required in the body for the following functions:

- Helps the body cells convert carbohydrates into energy
- Essential for the functioning of the heart, muscles, and nervous system.

The recommended dietary intake (RDI) for thiamin is: [2]

Children 1-3 years	0.5 mg
Children 4-8 years	0.6 mg
Children 9-13 years	0.9 mg
Boys 14-18 years	1.2 mg
Girls 14-18 years	1.1 mg
Men	1.2 mg
Women	1.1 mg
Pregnant women	1.4 mg
Lactation	1.4 mg

The RDI currently used for labelling purposes is 1.1 mg [1]

Sources

Sources of thiamin include egg yolk, wheatgerm, whole wheat products, yeast and yeast extracts, pulses, nuts, pork, duck and fortified breakfast cereal.

Amount in eggs

One serve of eggs provides 0.12 milligrams of thiamin, which is 11% of the RDI for adults.

People who may benefit from increased intakes of thiamin

- Pregnant and lactating women have greater requirements for thiamin. Breastfeeding babies of thiamine-deficient mothers are at risk for beriberi a collection of serious diseases that may affect the child's nervous system, heart, or brain [96]
- Thiamin deficiency is high in those who chronically drink alcohol to excess (a regular intake of at least 40g alcohol or 4 standard drinks a day) [4]Alcohol reduces thiamin absorption in the gut and increases its excretion from the kidneys.

- Populations who consume milled rice as a staple food are at risk of developing a thiamin deficiency. Most of the thiamin in rice is present in the outermost layer, which is removed during milling of rice and a large portion of the vitamin is also lost during cooking.[97]
- Those with a diet containing high amounts of thiaminase (an enzyme that destroys thiamine) such as raw freshwater fish, raw shellfish, ferns and/or foods high in anti-thiamine factors (tea, coffee, betel nuts) and by grossly impaired nutritional status associated with chronic diseases, such as gastrointestinal diseases, HIV-AIDS, and persistent vomiting may benefit from increased intakes of thiamin [97]
- It is thought that many people with diabetes have a deficiency of thiamin and that this may be linked to some of the complications that can occur [98]

Advantages of Thiamin from Eggs

Since thiamin is a water soluble vitamin, storage in the body is limited and dietary sources are therefore required daily. Eggs are a source of thiamin and can make a useful contribution to maintaining thiamin adequacy in at-risk populations.

Example communication messages:
- Eggs are a source of thiamin needed for conversion of carbohydrates into energy.

3.9 Riboflavin

Riboflavin is required in the body for the following functions:
- Release of energy from carbohydrate, protein and fat.
- Cell respiration

The recommended dietary intake (RDI) for riboflavin is: [2]

Children 1-3 years	0.5 mg
Children 4-8 years	0.6 mg
Children 9-13 years	0.9 mg
Boys 14-18 years	1.3 mg
Girls 14-18 years	1.1 mg
Men	1.2 mg
Women	1.1 mg
Pregnant women	1.4 mg
Lactation	1.4 mg

The RDI currently used for labelling purposes is 1.7 mg. [1]

Sources
Sources of riboflavin in the Australian diet include lean meats, eggs, legumes, nuts, green leafy vegetables and dairy products. Breakfast cereals are often fortified with riboflavin.

Amount in eggs
One serve of eggs provides 0.15 milligrams of riboflavin, which is 29% of the RDI for adults.

People who may benefit from increased intakes of riboflavin

- Studies suggest that riboflavin is beneficial in people with riboflavin deficiency (ariboflavinosis). Ariboflavinosis may cause weakness, throat swelling/soreness, glossitis (tongue swelling), angular stomatitis/cheilosis (skin cracking or sores at the corners of the mouth), dermatitis (skin irritation), or anemia.
- Particular groups may be especially susceptible to riboflavin deficiency, including the elderly. Mild riboflavin deficiency may be quite common in elderly people whose dietary intake is inadequate.
- Some studies have shown vegetarians to have lower intakes of riboflavin, compared with nonvegetarians, hence they may benefit from increased intakes of riboflavin.[99]
- People who are lactose intolerant and who cannot drink milk (which is a good source of riboflavin) may be at risk of deficiency. Those with malabsorption disorders, diarrhea and irritable bowel syndrome may also be at risk. Mild riboflavin deficiency may be quite common in elderly people whose diets are low in red meat and dairy products. Systemic infections, even without gastrointestinal tract involvement, may increase riboflavin requirements.
- People with malabsorption disorders, diarrhea, irritable bowel syndrome and those with alcohol dependency may also be at risk. Women during pregnancy, also have increased riboflavin requirements (an additional 0.3mg per day).

Advantages of riboflavin from Eggs

Since riboflavin is a water soluble vitamin, there is limited storage capacity so a regular intake from the diet is essential. Eggs are a rich source of riboflavin and can therefore make a useful contribution to riboflavin intakes.

Example communication messages:

- Eggs are a good source of riboflavin needed for conversion of food into energy.
- One serve of eggs provides almost a third of the recommended dietary intake for riboflavin.
- Eggs can be a particularly valuable inclusion in the diets of vegetarians whose diets may be low in dairy and red meat.

3.10 Vitamin B5

Vitamin B5 is required in the body for the following functions:

- Release of energy from carbohydrate, protein and fat.
- Synthesis of amino acids, fatty acids, sterols, steroid hormones and vitamin D.
- Formation of red blood cells
- Formation of acetylcholine (neurotransmitter)

The Adequate Intake (AI) for vitamin B5 is: [2]

Children 1-3 years	3.5 mg
Children 4-8 years	4.0 mg
Boys 9-13 years	5.0 mg
Girls 9-13 years	4.0 mg
Boys 14-18 years	6.0 mg
Girls 14-18 years	4.0 mg
Men	6.0 mg
Women	4.0 mg
Pregnant women	5.0 mg

There is currently no RDI for vitamin B5 for labelling purposes

Sources
Sources of vitamin B5 include eggs, poultry, meat, fish, liver, milk, sunflower seeds, soya beans, peas, peanuts, legumes, broccoli, whole grain products, mushrooms and wheat germ.

Amount in eggs
One serve of eggs provides 2.1 milligrams of vitamin B5, which is 42% of the RDI for adults.

People who may benefit from increased intakes of vitamin B5
- Vitamin B5 deficiency is exceedingly rare, and likely only occurs in cases of the most severe malnutrition. Most individuals likely obtain sufficient amounts from dietary sources.
- Vitamin B5 levels may be lower in alcoholics or people with insufficient food intake e.g. elderly, post-operative.

Advantages of vitamin B5 from Eggs

Eggs are a very rich source of vitamin B5 and contain over 40% of the RDI in one serving. They are an easy to prepare and nutritious meal choice which is beneficial for the elderly and others who have poor dietary intake.

Example communication messages:
- Eggs are a rich source of vitamin B5 needed for conversion of food into energy.
- One serve of eggs provides over 40% of the recommended dietary intake for vitamin B5.

3.11 Vitamin B12

Vitamin B12 is required in the body to carry out the following functions:
- Forms and regenerates red blood cells
- Needed for production of DNA (genetic material)
- Needed to maintain a healthy nervous system
- Involved in carbohydrate, protein and fat metabolism

The recommended dietary intake (RDI) for vitamin B12 is [2]:

Children 1-3 years	0.9µg
Children 4-8 years	1.2µg
Children 9-13 years	1.8µg
Adolescents 14-18 years	2.4µg
Adults	2.4µg
Pregnancy	2.6µg
Lactation	2.8µg

The RDI currently used for labelling purposes is 2.0µg [1].

Sources
Vitamin B12 is only found in animal foods such as meat, poultry, seafood, shellfish, eggs, cheese, yoghurt and milk. Some foods, particularly those targeting vegetarians, may be fortified with vitamin B12, for example, some soy beverages.

Amount in Eggs

Egg yolks are an excellent source of vitamin B12, with one serve providing 0.8micrograms (40% of the RDI for adults). Vitamin B12 enriched eggs, such as the Body Egg, are also available in Australia.

People who may benefit from increased intake of this nutrient

- People who eat insufficient quantities of animal based foods, such as adolescent girls. As the body stores vitamin B12, symptoms of deficiency can take up to 3-6 years of poor dietary intake to appear. Deficiency is also more likely to result due to decreased absorption, as occurs with a lack of intrinsic factor (a substance produced in the stomach that assists in absorption of vitamin B12 from the small intestine).
- Elderly people are at risk of vitamin B12 deficiency as they generally consume less food, and therefore less vitamin B12. Results from the Blue Mountains Eye study show that 11% of women and 9% of men in the older population do not consume adequate amounts of vitamin B12 [100]. Ageing also results in a decreased production of intrinsic factor and atrophy of gastric mucosa, contributing to suboptimal levels of vitamin B12 [5]. There is increasing evidence that elderly people may have higher requirements for vitamin B12 [101]. In recognition of this, the US Dietary Reference Intakes recommend that older adults meet their vitamin B12 needs from supplements or foods fortified with vitamin B12 [102]. Studies also suggest that cognition in the elderly may be adversely affected at low levels of vitamin B12 in the blood above the traditional cut-offs for deficiency. A recent study[103] found cognitive decline in older adults (average age 74.8 years) was significantly faster in those with low vitamin B12 levels and appeared to be further accelerated if the low vitamin B12 was accompanied by higher blood folate levels.
- Hence, the elderly in particular should be encouraged to maintain a good, rather than just an adequate, vitamin B-12 status. [104]
- Vegetarians often consume inadequate amounts of vitamin B12. Vegans who also exclude dairy products are at an even higher risk of deficiency and it has been estimated that 92% of vegans have sub-optimal levels of vitamin B12 in the body [105]. As a consequence of decreased intake, maternal stores are also low, and lower levels are secreted in breast milk, which increases risk of deficiency in the children of vegetarian mothers [5].
- As athletes often have a high red blood cell turnover, increased intake of B12 may be beneficial for regeneration of new red blood cells.
- A 2010 study shows that vitamin B12 may protect against Alzheimer's disease, giving further support for the vitamins effectiveness in reducing the risk of memory loss[106].

Advantages of Vitamin B12 from Eggs

Compared to other food sources of vitamin B12, eggs are cheap and easy to prepare. They are one of the few sources of vitamin B12 in the diets of ovo-vegetarians. Eggs also provide folate, which works with vitamin B12 to maintain healthy red blood cells.

Example communication messages:

- Eggs are an excellent source of vitamin B12 needed for healthy red blood cells.
- One serve of eggs provides almost half of the recommended dietary intake for vitamin B12.
- Eggs can be a particularly valuable inclusion in the diets of vegetarians as they provide vitamin B12, a nutrient often low in vegetarian diets.
- Eggs can be a particularly valuable inclusion in the diets of the elderly as requirements for vitamin B12 increase with ageing.

3.12 Iron

Iron is required daily in the diet for the following functions:

- Carries oxygen around the bloodstream and used for oxygen storage in muscles
- Improves immunity
- Required for growth
- Required for energy production in the body
- Needed for optimal mental functioning

The recommended dietary intake (RDI) for iron is [2]:

Children 1-3 years	9mg
Children 4-8 years	10mg
Children 9-13 years	8mg
Boys 14-18 years	11mg
Girls 14-18 years	15mg
Men	8mg
Women 19-50 years	18mg
Women over 51 years	8mg
Pregnancy	27mg
Lactation	9mg

The RDI currently used for labelling purposes is 12mg [1].

Sources

Iron in food exists in 2 forms: heme and non-heme. As a general rule, heme forms are predominant in animal products, while non-heme forms dominate in plant sources. Heme iron is much more readily absorbed by the body. Eggs contain iron in both forms [107]Sources of heme iron include lean red meat, seafood, chicken and fish while non-heme iron is found in fortified cereals and drink powders, dark-green vegetables, wheat germ, dried fruit, oatmeal and nuts, wholemeal bread, legumes and cocoa powder.

Amount in eggs

One serve of eggs provides 1.7mg of iron, which represents 14% of the RDI for adults. Researchers have looked at fortifying eggs with iron, such that iron content may be increased by as much as 20% per egg [108].

People who may benefit from increased intakes of iron

- Women of childbearing age are at high risk of iron deficiency anaemia due to monthly menstrual losses [109]. The National Nutrition Survey [8] shows that on average, women aged 19-24 do not meet even the lower end of the RDI, with average intakes being 11.9mg per day. The recent increase in the iron RDI to 18mg for women means that an even lower proportion of this population sub-group may now be meeting the revised recommendation.
- In pregnancy, the RDI increases by two to three fold. Intake of iron rich foods is extremely important during this time to ensure a healthy outcome [109,110].
- Athletes are at risk of iron deficiency. Increased red blood cell turnover increases requirements for iron. In some sports, athletes reduce food intake to qualify for weight categories, which can also put them at risk of deficiency due to decreased food intake.

- Infants and weaning toddlers can become iron deficient due to decreased intake of iron [109]. During transition from the breast or bottle to solid foods, poor food choices can predispose children to iron deficiency, which can result in potential cognitive impairment. Iron stores in breast-fed infants become depleted by around six months of age [109].
- Vegetarians are at risk of iron deficiency due to decreased intake of iron from highly bioavailable sources, and lower level bioavailability of non-heme iron found in plant sources [111].

Advantage of iron from eggs

Eggs contain both heme and non-heme iron, however eggs are classified as a food that has a low iron bioavailability at around 5% compared to red meat at 15% [5] due to egg white inhibiting iron absorption [112]. Iron absorption from egg yolk alone has not been investigated [113]. However non-heme iron absorption can potentially be increased if eggs are consumed with orange juice or other sources of vitamin C [5].

Example communication messages:

- Eggs provide a valuable source of iron for groups at risk of iron deficiency including vegetarians, toddlers, pregnant women and athletes.

3.13 Zinc

Zinc is required by the body to carry out the following functions:

- Maintenance of a strong immune system
- Wound healing
- Needed for healthy eyes and skin and for growth and sexual development
- Involved in the activity of over 200 enzymes in the body
- Synthesis of genetic material and proteins

The recommended dietary intake (RDI) for zinc is [2]:

Children 1-3 years	3mg
Children 4-8 years	4mg
Children 9-13 years	6mg
Boys 14-18 years	13mg
Girls 14-18 years	7mg
Men	14mg
Women	8mg
Pregnant women	11mg
Lactation	12mg

The RDI currently used for labelling purposes is 12mg [1].

Sources
Sources of zinc include lean red meat, oysters, crab and shellfish, chicken, Brazil nuts, oily fish, whole grains, wholemeal bread, sesame and sunflower seeds, oat bran, egg yolk, milk, nuts and pulses.

Amount in eggs
One serve of eggs contains 0.5mg of zinc, which is 4% of the RDI. Zinc enriched eggs, such as the Body Egg, are also available in Australia.

People who might benefit from increased intakes of zinc

- The 1995 National Nutrition Survey showed that on average, women did not meet the RDI for zinc. In the 19-24 year age group, intake averaged 10.2mg per day. This fell to 9.9mg per day and 9.8mg per day in the 25-44 year and 45-64 year age groups respectively [8]. Around 13% of teenage boys aged 14-16 years have intakes lower than the EAR [9].
- As requirements for zinc are increased during pregnancy and lactation, suboptimal zinc intakes are more likely in this population sub-group [114].
- A study of people aged 44 years and over in Australia showed 69% of males and 83% of females did not meet the RDI for zinc [32]. Zinc deficiency can increase susceptibility to infection, decrease taste sensation and appetite, and lead to poor wound healing and night blindness, all of which can jeopardise health in older Australians.
- Vegetarians often have inadequate intakes, as meat and seafood is a common source of zinc in the diet [114].

Advantages of zinc from eggs
Animal protein enhances zinc bioavailability and eggs are a source of animal protein. This is advantageous compared to cereal sources of zinc; however, the majority of zinc in the Australian diet comes from meat, fish, poultry, followed by cereals and dairy products.

Example communication messages:

- Eggs provide small amounts of zinc which may be particularly useful in a vegetarian diet where animal sources of zinc are restricted.
- Eggs provide small amounts of zinc which may be particularly useful in the diet of older Australians as many do not meet recommended dietary intakes.

3.14 Selenium

Selenium is required by the body to carry out the following functions:

- Needed for synthesis of thyroid hormones, which regulate basal metabolic rate
- Antioxidant function - works with vitamin E as part of a key antioxidant enzyme (glutathione peroxidase)

The recommended dietary intake (RDI) for selenium is [2]:

Children 1-3 years	25µg
Children 4-8 years	30µg
Children 9-13 years	50µg
Boys 14-18 years	70µg
Girls 14-18 years	60µg
Men	70µg
Women	60µg
Pregnant women	65µg
Lactation	75µg

The RDI currently used for labelling purposes is 70µg [1].

Sources

In Australia and New Zealand, the main dietary sources are seafood, poultry and eggs, followed by some meats. Other sources of selenium include Brazil nuts, mushrooms, whole grains, and wheat germ. However the contribution of selenium from cereal products depends on the available selenium in the soil in which the food is grown [115]. In Australia, half of people's selenium intake is estimated to come from wheat [115].

Amount in eggs

A serving of eggs provides 41µg of selenium, representing 59% of the RDI. Selenium enriched eggs, such as the Body Egg, are also available in Australia.

People who may benefit from increased intakes of selenium

Selenium intake was not monitored in the National Nutrition Survey, however the 2008 Australian Total Diet Study conducted by FSANZ suggests Australians' intake of selenium is low [116]. An earlier South Australian study published in the Medical Journal of Australia [115] found that mean blood plasma selenium concentrations were at an adequate level for maximisation of antioxidant activity. This, however, was lower than a proposed plausible target level for cancer risk reduction. The researchers also concluded that it is likely that many South Australians do not consume enough selenium to maximise selenoenzyme expression, a key enzyme required for reducing cell membrane damage [115].

Groups at high risk of selenium deficiency identified by researchers include [117]:

- Smokers. Selenium is important in this group due to its antioxidant properties, which protect cells from chemical damage [118].
- Men at increased risk of prostate cancer as evidence suggests selenium may be protective (however currently inconclusive) [119].
- Pregnant and lactating women, as the RDI increases during this time [120].
- Frail elderly who are at increased risk of suboptimal intakes [121].

Further research has shown:

- Selenium may play a role in reducing the risk of developing the metabolic syndrome. Serum C3, a predictor of the metabolic syndrome, was lowest in patients who had the highest levels of selenium in the body [122]
- One study has shown that higher selenium levels in the blood may increase cholesterol levels, however the amount in one serve of eggs is unlikely to lead to adverse levels in the blood. [123]

Advantages of selenium from eggs
Vitamin E and iodine, both of which are found in eggs, assist the functioning of selenium. As a major source of selenium in Australia is wheat [124], in those who consume lower carbohydrate diets or those who cut wheat out of their diet, may be at greater risk of sub-optimal selenium levels in the population.

Example communication messages:

- Eggs are an excellent source of selenium, a trace mineral required for many functions in the body.
- Eggs are an excellent inclusion in a lower carbohydrate eating pattern due to the presence of selenium, a powerful antioxidant that can be low when following this style of eating.

3.15 Iodine

Iodine is a mineral essential for normal thyroid function and production of thyroid hormones, which are involved in regulating metabolism and development and differentiation of cells.

The recommended dietary intake (RDI) for iodine is [2]:

Children 1-8 years	90µg
Children 9-13 years	120µg
Adolescents 14-18 years	150µg
Men	150µg
Women	150µg
Pregnant women	220µg
Lactation	270µg

The RDI currently used for labelling purposes is 150µg [1].

Sources
Iodine is found in foods such as eggs, kelp and seafood, but the main dietary source is iodised salt. Australian and New Zealand bread is now fortified with iodine due to the mandatory use of iodised salt from 2009 to help increase population intakes of this important mineral. A study in German preschoolers showed milk, salt and eggs to be the 3 biggest contributors to iodine intakes[125].

Amount in eggs
A serve of eggs contains 43µg of iodine, 29% of the RDI.

People who may benefit from increased intakes of iodine

- About 40-50% of Australian pregnant women have mild iodine deficiency [126]. Iodine deficiency during pregnancy can cause miscarriage, stillbirth and mental impairment [120] and as the RDI for iodine increases to 220 µg/day and 270µg/day during pregnancy and lactation respectively, these women who already use salt are advised to use iodized salt [127]. Others may benefit from an iodine supplement to improve their iodine status throughout their pregnancy [128].Recent Australian data shows 70% of women and 10% of children have inadequate intakes of iodine [116]. Increasing dietary intakes of iodine in these groups is therefore recommended.The World Health Organisation has recently increased the recommended iodine intake during pregnancy from 200µg per day to 250µg per day and advises supplementation in certain conditions. [129]
- Recent research has confirmed that Australian children and pregnant women are mildly iodine deficient. A considerable proportion of the pregnant population is moderately to severely iodine deficient[130].

Example communication messages:

- Eggs are an excellent source of iodine.
- Eggs are one of the few natural sources of iodine.

3.16 Choline

Choline is a type of phospholipid required by the body to carry out the following functions:

- Cholesterol and fat metabolism, and transport of fat from the liver
- Production of the neurotransmitter acetylcholine, which is involved in nerve and brain functioning and memory
- As a component of myelin, the insulating sheath around nerves
- To maintain healthy cell membranes

The Adequate Intake (AI) values for choline in Australia are as follows [2]:

Children 1-3 years	200mg
Children 4-8 years	250mg
Children 9-13 years	375mg
Boys 14-18 years	550mg
Girls 14-18 years	400mg
Men	550mg
Women	425mg
Pregnant women	440mg
Lactation	550mg

There is currently no RDI for choline for labelling purposes.

Sources

Sources of choline include eggs, organ meats (liver, kidney, and brain), green leafy vegetables, wheat bran and germ, pulses, lecithin (the richest source of choline), soybeans, grains and nuts (particularly peanuts).

Amount in eggs
According to the Egg Nutrition Centre, Washington, DC one 50gram egg contains 280mg of choline. An Australian reference estimates the choline content of eggs as 420mg per 100g [4]. However nutrient testing by AECL has yet to confirm this level. Choline is part of the phospholipid lecithin in eggs.

People who may benefit from increased intakes of choline

- It has been estimated that on average, Australian choline intake is 600 – 1000mg per day, which is above estimated requirements [4].
- Choline intake is of particular interest during pregnancy and lactation. Choline cannot be synthesized in sufficient quantities within the body to meet metabolic demands and therefore must be acquired through the diet. Requirements for choline are increased at this time as it is transported through the placenta and mammary gland to the developing infant [131]. Choline is required for the normal development of brain tissue in infants. A recent study in mice showed that those who did not receive choline while in the womb had genetic differences in their brain cells compared to the group who did receive choline, further supporting the role of choline in pregnancy [132] Other studies have documented choline's important role in brain development and cognition with particular importance given to adequate choline in pregnancy.For example, levels of choline and betaine at week 16 of pregnancy was found to be associated with better cognitive test scores in 18 month old infants[133]. Choline appears to work actively in the brain regions responsible for memory and learning[134].
- Another study in more than 180,000 pregnant women already supplemented with folate found that higher levels of total blood choline was associated with a 2.5-fold reduction in risk for neural tube birth defects (NTDs). NTDs are birth defects of the brain and spinal cord, and the two most common NTDs are spina bifida and anencephaly.[135]
- Choline may play a role in preventing heart disease through reducing levels of homocysteine in the blood, a risk factor for heart disease. It may therefore be of benefit to those with high homocysteine levels and/or those at high risk of heart disease.
- A study funded by a grant from the National Institutes of Health (NIH) found that the risk of developing breast cancer was 24 percent lower among women with the highest intake of choline compared to women with the lowest intake.[136]
- In the elderly, a feature of Alzheimer's disease is abnormal phospholipid metabolism that results in reduced levels of choline and other metabolites in the brain. It has been proposed that membrane phospholipids are broken down to supply choline for acetylcholine synthesis. Further research is required before any conclusions regarding the role of dietary choline in preventing Alzheimer's disease can be made.
- Vegetarians consuming significant quantities of refined food products have a risk of becoming choline deficient [2].
- Higher intakes of choline have led to improvements in verbal and visual memory, suggestive of cognitive benefits[137].
- An animal study has shown that choline during pregnancy and nursing could provide lasting cognitive and emotional benefits to individuals with Downs syndrome and protect against conditions such as Alzheimer's disease[138].
- People with non-alcoholic fatty liver disease had more fibrosis with inadequate choline status.[139]
- Low blood levels of choline and betaine have also been associated with poor cognitive performance in older adults (aged 70-74years)[140].

One negative study was published in 2012 showing men with prostate cancer who had the highest intake of choline prior to diagnosis had a 70% increased risk of lethal prostate cancer[141].

Advantages of choline from eggs

Choline has a high bioavailability from eggs compared to other foods [102]. Eggs provide more choline per kilojoule compared to most other foods. To get the same amount of choline found in a single egg (125 mg/301 kilojoules; most of the choline is in the egg yolk – 680 mg/100 g), one would need to consume 3¼ cups of skim milk (1130 kilojoules) or 99g of wheat germ (1532 kilojoules). In addition, adding an egg to the diet each day would increase the number of pregnant women meeting the AI from 10% to more than 50% and for older men and women from 5% to 20%. [142]. Eggs also contain vitamin B12, folate and methionine which could be used to synthesize choline in the body.

Example communication messages:

- Eggs are one of only a few food sources of choline.
- Choline is particularly useful in the diet of pregnant and lactating women. Eggs are therefore highly recommended at this time of life.

4. Scientific Review of the Antioxidants in Eggs - Lutein and Zeaxanthin; Tyrosine & Tryptophan

In addition to their many micronutrients, eggs also contain a number of compounds with known antioxidant properties. Egg yolks in particular contain lutein and zeaxanthin. These are two fat-soluble compounds belonging to a class of carotenoids called xanthophylls, and they are considered to be beneficial in decreasing the risk of several major disease states. It has also been recently discovered that the amino acids tyrosine and tryptophan found in eggs have antioxidant properties[143]. The same study showed egg yolk contain similar levels of antioxidants compared to fruit and vegetables although cooking (particularly microwaving) the egg yolk did reduce both the level and activity of the antioxidants. Similarly, cooking has been shown to effect lutein and zeaxanthin concentrations with losses ranging between 6-18%[144]. The main differences between raw and cooked eggs was the chemical structure of lutein, changing from predominately E-isomer to Z-isomer. Whether this change in structure has any impact nutritionally is currently unknown.

4.1 Dietary Sources, Bioavailability and Consumption of Lutein and Zeaxanthin

Fruit and green vegetables are the most abundant sources of dietary lutein and zeaxanthin, and are the major contributors to the typical human diet [145,146]. Until recently, lutein and zeaxanthin were measured together because analytical procedures did not permit separate quantification of these carotenoids in foods. The following table shows the lutein and zeaxanthin content of a number of foods.

Table 1: Lutein and Zeaxanthin Content of Common Foods

Food	Lutein and zeaxanthin (mg/100g)
Spinach	12.2
Frozen green peas (boiled)	2.4
Lettuce	1.7
Broccoli (boiled)	1.1
Pumpkin (boiled)	1.0
Frozen corn (boiled)	0.7
Whole egg	0.51*

Sources:
USDA National Nutrient Database for Standard Reference, Release 19 (2006)
*Nutrient testing performed by AECL, November 2007

As shown, the amount of lutein and zeaxanthin in eggs is lower than some vegetables, however the bioavailability of these compounds from eggs may be higher [147].

It has been shown that the bioavailability of carotenoids is determined by the characteristics of the food in which they are contained and with the interactions they have with other dietary constituents. The egg yolk is a matrix of digestible lipids, with lutein and zeaxanthin dispersed within it, along with other fat-soluble micronutrients. Lutein and zeaxanthin in egg yolks may be highly bioavailable due to their association with this lipid matrix [148]. Olive oil has also been shown to enhance their absorption [149]. In contrast, the localisation of carotenoids within the chloroplasts and chromoplasts of plants may decrease bioavailability [150]. Furthermore, dietary fibre from plant sources, such as pectin and guar gum, has been shown to reduce carotenoid absorption [151].

The intake of carotenoids varies in different populations and varies seasonally. For example, in Europe, the average daily intake of major carotenoids ranges from 3.5mg/day in the Spanish population [152] to 5.33mg/day in the German population [153].

Fewer studies have specifically measured lutein and zeaxanthin consumption in populations, however in an American study of elderly subjects, daily consumption of lutein and zeaxanthin was 2.7mg for men and 3.09mg for women [154]. In another study, it was estimated that American adults consume approximately 1-2mg of lutein per day [155]. In the US, the national intakes of lutein may be declining. According to National Health Interview Studies, there was a decrease in lutein consumption amongst different categories of people between 1987 and 1992 due to decreased intakes of green leafy vegetables [156]. In a UK study, the intake of lutein was significantly higher in spring compared with summer and autumn [157].

In an Australian study of an elderly population living in the Blue Mountains, it was found that the average intake of lutein and zeaxanthin was 0.9mg and that women had slightly higher intakes than men [158]. The main contributors to lutein and zeaxanthin intakes were broccoli, green beans and oranges. No other Australian studies have assessed the intake of these antioxidants in other population sub-groups however current intakes in elderly people are lower than ideal.

Due to both their high bioavailability and not being subjected to seasonal variation, the consumption of eggs may be a favourable source of lutein and zeaxanthin in the diet.

The level of antioxidants, using the ORAC measurement, in eggs compared to other fruits and vegetables is set out in the table below.

	Food Type	**ORAC (Umol TE/100g)**
FRUIT*	Apple (Fuji)	2589
	Apple (Granny Smith)	3898
	Bananas	795
	Blueberries	4669
	Grapes (red)	1837
	Oranges	1819
	Strawberries	4302
VEGETABLES*	Asparagus (cooked)	1644
	Broccoli (boiled)	2160
	Carrots (boiled)	326
	Corn (raw)	728
	Spinach (raw)	1513
	Tomatoes (raw)	546
EGGS[143]	Egg Yolk (wheat-fed) Boiled	**3904**
	Egg Yolk (wheat-fed) Fried	**2572**
	Egg Yolk (wheat-fed) Raw	**3506**
	Egg Whole (wheat-fed) Boiled	**1366**
	Egg Whole (wheat-fed) Fried	**900**
	Egg Whole (wheat-fed) Raw	**1227**

* Nutrient Data Laboratory (2010). USDA Database for the Oxygen Radical Absorbance Capacity (ORAC) of Selected Foods, Release 2, 2010, 48.

4.2 Antioxidant Enrichment of Eggs

The manipulation of the feed of laying hens, most commonly through the addition of marigold extract, has allowed for the development of antioxidant-enhanced eggs, which are currently available in some countries. For example, an egg has been developed in Scotland that has a carotenoid content 16 times greater than that of a standard egg [145]. A standard serve of eggs contains approximately 0.12mg lutein, whereas this 'designer' egg contains 1.91mg lutein. In Finland, commercially available eggs have been analysed for their carotenoid content and have been shown to contain 0.25mg lutein in the egg yolk [159]. Eggs can be enriched with lutein by modifying the diet of the chickens, a 2004 animal study showed. The increase in lutein was as much 1.2mg per 60g of egg [160]. Lutein-enriched eggs (GoldPlus) have previously been available in Australia.

The antioxidant fortification of eggs and subsequent availability as an everyday food may serve to improve the lutein and zeaxanthin content of the diet of individuals.

4.3 Potential Health Benefits of Lutein and Zeaxanthin

Lutein and zeaxanthin may play a critical role in the maintenance of normal visual function [161]. A scientific review has confirmed that an optimal supply of lutein and zeaxanthin are essential for eye health[162]. The authors emphasise the potential of these nutrients for protection of the eye and the prevention and treatment of age-related eye diseases, such as macular degeneration (AMD) in the elderly[162]. Given that these two compounds are the only carotenoids found in the retina and lens, and that the retina and lens suffer progressive oxidative damage, it has been thought for some time that lutein and zeaxanthin may play a protective role in the prevention against eye disease [161]. In reviews of human studies, evidence suggests that the dietary intake of plant based lutein and zeaxanthin can lead to their accumulation in the retina, and as a result may provide protection against retinal degeneration [147,163]. Research has also found a high proportion (79%) of subjects with wet AMD have a deficient intake of lutein and zeaxanthin[164]. Furthermore, population studies have shown that lutein and zeaxanthin may also provide protection against age-related cataracts [165] and age-related macular degeneration (AMD)[163,166]. Experimental studies have shown that lutein supplements may protect the eye from AMD [167] or slow the progression of the disease in those who have early AMD. A study has also shown that a daily supplement of lutein in combination with vitamin A may slow vision loss associated with retinitis pigmentosa - a group of inherited eye diseases that affect the retina and brings progressive vision loss[168]. Several mechanisms have been proposed as to how lutein and zeaxanthin may protect the eye. It is known that macular pigment (MP) filters blue light, which is damaging to photoreceptors and to the retinal pigment epithelium. One study [169]showed that retinal lutein and zeaxanthin reduce glare disability and discomfort, reduce photostress recovery times, and enhance contrast. MP improves glare performance through absorption of forward scattered short-wave (blue) light. There is also data (albeit preliminary) to support the idea that MP increases visual range by absorbing short-wave scattered light in the atmosphere. MP also appears to enhance colour contrast). It is also known that light can damage the retina via the generation of free radicals. The antioxidant properties of lutein and zeaxanthin may therefore reduce this free radical destruction [147]. Although it is unclear why some people develop AMD it has been suggested there may be a problem with the uptake of lutein and zeaxanthin by the eye [170].Despite all this research, the Academy of Nutrition and Dietetics released guidelines in 2012 stating research regarding antioxidant intakes (including lutein and zeaxanthin) below or above the RDA (Recommended daily allowance) and risk of age-related macular degeneration was inconclusive[171] but there was some evidence that supplementation did delay the progression of AMD.

The Blue Mountains Eye Study (BMES) showed that for dietary lutein and zeaxanthin, elderly participants in the top tertile of intake had a reduced risk of developing late AMD (RR 0.35). This data showed that in older Australians, those with a dietary lutein and zeaxanthin intake of more than 942mcg/day, along with the highest intake of vegetables, were less likely to develop AMD [172]. However other previous studies have had less convincing results. The Nurses Health Study and the Health Professional Follow Up Study showed no protective effect of vegetables, antioxidant vitamins or carotenoids on age related macular degeneration [173]. In this study, only fruit intake was protective. Older data from the BMES showed that the average intake of lutein and zeaxanthin was 914 micrograms [158], but an association between usual dietary antioxidant or zinc intakes (including use of supplements) on the 5-year incidence of early AMD was not found [174]. The Beaver Dam Eye Study showed only a weak association between dietary antioxidants and eye health [175] and a 2003 review of the literature shown that there may be an association, but it is not statistically significant [176]. Some experts suggest that the consumption of antioxidants, including lutein, from foods should be encouraged in light of the chance that it may prevent retinal damage, among other health benefits [177].

The potential cancer-preventing actions of carotenoids have also been assessed. Although beta-carotene has been extensively studied, more recent investigations have addressed the association between individual carotenoid intake, including lutein and zeaxanthin, and cancer risk. In a 14 year follow up of a large cohort study of 27,084 male smokers, a significant inverse association was observed between lutein/zeaxanthin and risk of any type of lung cancer, even after adjusting for smoking [178]. Although earlier observational studies examining the relation between individual dietary carotenoids and lung cancer risk yielded inconsistent findings, a review of more recent studies using updated carotenoid databases suggest that carotenoids other than beta-carotene, or a combination of carotenoids, may have the potential for the prevention of lung cancer [178].

The importance of specific dietary carotenoids in relation to breast cancer risk, have been investigated. The relation between dietary intake of lutein/zeaxanthin and risk of breast cancer was assessed in an 11-year follow-up of a large cohort analysis of 56,837 women [179]. After adjusting for potential confounders including smoking, relative body weight, family history and other parameters, no associations were observed between individual carotenoids and breast cancer risk. However, in another large cohort study of 83,234 women, with a 14-year follow-up, an inverse association was found between lutein/zeaxanthin and breast cancer risk in premenopausal women [180]. In support, a review of 20 case-control studies generally supports a consistent inverse association between dietary carotenoids and risk of breast cancer [179]. Further studies are warranted before conclusions can be drawn in relation to the role of specific carotenoids and breast cancer risk.

Attention has also focused on the role of individual carotenoids in the prevention of cardiovascular disease. Data presented from a study combining a prospective epidemiological investigation of atherosclerosis progression, an *in-vitro* model of oxidation in the artery wall and an *in-vivo* mouse model of atherosclerosis, supported a finding that increased dietary intake of lutein is protective against the development of early atherosclerosis [181]. The epidemiological findings have been somewhat supported by a large case-control study that investigated an association between levels of several antioxidants and myocardial infarction (MI). In this study, cigarette smokers with a history of MI demonstrated a significantly increased risk for subsequent MI with decreasing levels of beta-carotene and a suggestive trend with decreasing levels of lutein [182]. In contrast though, data from a 2003 large prospective study of 73,286 women identified no significant association between intakes of lutein/zeaxanthin and reduced risk of coronary artery disease [183]. More recently data from a 2012 study showed subjects with heart disease had significantly lower blood levels of lutein and zeaxanthin compared to healthy controls[184]**.** The study also found associations between levels of carotenoids and inflammatory markers which suggests a possible protective mechanism.

Studies have indicated that a proportion of the population who are hyper-responsive to dietary cholesterol may also elicit a higher plasma response to lutein and zeaxanthin [185], probably because lutein and zeaxanthin are transported by cholesterol particles in the body. Forty study participants who were fed 3 eggs per day for 30 days showed that plasma concentrations of lutein were significantly elevated in the egg treatment group compared to the control group ($P<0.01$), while hyper-responders were also found to have significantly greater increases in plasma lutein after the egg period compared with hypo-responders ($P <0.05$). The hypo-responders exhibited only half the plasma lutein increase that occurred in the hyper-responders. These results show that there may be an individual variability in response to dietary carotenoid intake, therefore the effects of lutein and zeaxanthin on disease prevention may vary within the population. A similar study among 42 postmenopausal women and men aged sixty years and over with healthy lipoprotein profiles [186] showed consumption of three eggs per day for one month increased plasma lutein and zeaxanthin concentrations to a larger degree than hypo-responders ($P<0.05$). Furthermore, the impact of egg consumption on plasma lutein levels appears to be influenced by body mass index and waist circumference. A cross-over study in 22 postmenopausal women showed that improvements in plasma lutein after egg consumption were less likely in those with a body mass index above 29. This was irrespective of changes in plasma cholesterol [187].

Another benefit associated with lutein and zeaxanthin is the potential to improve cognitive functioning, particularly in the elderly. It is known that lutein and zeaxanthin accumulate in the brain[188] and low plasma levels of lutein and zeaxanthin have been seen in those with poor cognitive function [189]. Further evidence has been highlighted in a recent review[188]. An examination of a relation between cognition and lutein and zeaxanthin concentrations in the brain tissue of decedents from a population-based study in centenarians found that zeaxanthin concentrations in brain tissue were significantly related to measures of global cognitive function, memory retention, verbal fluency, and dementia severity after adjustment for age, sex, education, hypertension, and diabetes. Furthermore, in a trial in older women that involved lutein supplementation (12 mg/d), alone or in combination with DHA (800 mg/d), verbal fluency scores improved significantly in the DHA, lutein, and combined-treatment groups. Memory scores and rate of learning improved significantly in the combined-treatment group, who also showed a trend toward more efficient learning. Despite this accumulating evidence it is unclear if these associations are causal or whether lutein and zeaxanthin supplementation is able to prevent cognitive decline in aging.

Found naturally in the skin, lutein and zeaxanthin may also protect the skin against damage from UV rays and help reduce premature aging. A recent study found that oral or topical treatment with lutein and zeaxanthin either individually or in combination raised the antioxidant activity of the skin [190].

A study has also looked at the association between total and individual carotenoid intake (α-carotene, β-carotene, β-cryptoxanthin, lycopene, and lutein+zeaxanthin) and changes in bone mineral density (BMD) in older men and women. Results showed that total carotenoids, β-carotene, lycopene and lutein+zeaxanthin were associated with a higher BMD at the hip in men but not women. [191]

In conclusion, research supports a potential protective role of lutein and zeaxanthin in some disease states, especially eye disease and in some cancers. These data have not been consistent and further studies are required. It must be noted that all of the studies examining the potential health benefits of lutein and zeaxanthin were performed using plants as the primary source of dietary carotenoids. Although it has been known for some time that eggs are a source of dietary carotenoids, their high bioavailability has only recently been established. Studies related to antioxidants in eggs and their potential health benefits are only just emerging.

4.4 Lutein and Zeaxanthin in Eggs and Potential Health Benefits

To date, we have not identified any studies that have specifically investigated associations of antioxidants from egg consumption with disease risk. However, in the Beaver Dam Eye Study, egg consumption was inversely associated with nuclear cataract risk among members of the cohort who were less than 65 years of age at baseline [175]. Persons in the highest quintile of egg consumption had a 60% lower risk of developing cataract compared to those in the lowest quintile of intake. However, a number of studies have assessed egg consumption as a vehicle for increased antioxidant/carotenoid uptake.

In a study of mildly hypercholesterolaemic men, supplementation of 1.3 cooked egg yolks per day resulted in up to a 50% increase in plasma lutein (from 0.269 to 0.403umol/L) and 142% increase in plasma zeaxanthin (from 0.048 to 0.012umol/L), depending on the baseline diet [148]. An examination of individual responses to egg carotenoid intake showed an increase in plasma zeaxanthin in every subject after egg yolk supplementation [148]. This study demonstrated that egg yolks provide a highly bioavailable source of lutein and zeaxanthin, however potential health benefits as a result of increased antioxidant update can only be implied.

A similar study among 33 men and women aged 60 years and over found that eating one egg a day for five weeks significantly increased the levels of serum lutein and zeaxanthin without increasing blood cholesterol levels [192]. Serum lutein concentration increased by 26% from baseline while zeaxanthin increased by 38% ($P<0.05$ for both increases). Serum total cholesterol, LDL, HDL and triglycerides did not differ between the egg and no-egg treatment phases.

In a study that evaluated the ability of 'designer' eggs enriched in vitamin C, lutein, selenium and docosahexaenoic acid (DHA) to deliver micronutrients, consumption of one designer egg per day when compared to an intake of a normal egg, resulted in a 1.88-fold increase in plasma lutein [145]. In this study, individuals receiving the designer egg demonstrated a small decrease in systolic blood pressure (4mm Hg) and a slight increase in HDL-cholesterol (an increase to 1.25mmol/L). Specific health benefits or disease risks were not assessed in this study.

To further investigate the potential role of dietary carotenoids in protecting against macular degeneration, a 2003 study evaluated the influence of egg consumption as a source of macular carotenoids [193]. In this study, the consumption of 6 eggs per week significantly increased the concentration of macular carotenoids (as measured by macular pigment optical density) as well as serum zeaxanthin levels; however serum lutein levels remained unchanged [193]. This observation of increased delivery of carotenoids to the retina and lens may only imply a benefit to visual function; as such an association was not directly assessed. Similarly, a recent study showed that eating six eggs a week for 12 weeks increased macular pigment optical density (MPOD) without increasing blood cholesterol levels in 24 females aged 24-59 years [194]. Serum zeaxanthin also increased in the egg treatment groups. Because greater macular pigment density means better protection of the eyes, these results suggest that there may be a potential role in reducing the risk of ARMD.

Another study tested the effect of eating 2 and 4 egg yolks per day on blood levels of lutein and zeaxanthin and macular pigment optical density (MPOD) in adults taking cholesterol lowering medications. Subjects consumed foods containing 2 followed by 4 egg yolks/day for 5 weeks each with a 4-wk egg-free period at baseline and between the 2 interventions. Results showed that consumption of 2 and 4 egg yolks per day for 5 weeks increased MPOD and benefited macular health in older adults with low MPOD. Blood levels of lutein and zeaxanthin were raised with increasing intakes of egg, as was "good" HDL cholesterol. On the contrary, "bad" LDL cholesterol did not change.[195]

A 2012 study also assessed egg consumption as a vehicle for increasing carotenoids looking specifically at effects in people with the metabolic syndrome[196]. Study participants consumed 3 whole eggs per day or the equivalent amount of yolk free egg substitute as part of a carbohydrate restricted diet for 12 weeks. After 12 weeks those who had consumed the eggs had significant increases in blood levels of lutein, zeaxanthin and beta-carotene while those consuming the egg substitute only had increases in beta-carotene. The egg group also had significant enrichment of HDL and LDL cholesterol fractions with lutein and zeaxanthin which suggests better transport of lutein and zeaxanthin via HDL particles to key tissues such as the retina of the eye (providing protection from AMD) and lutein may protect LDL particles from oxidation (oxidised LDL increases risk of heart disease).

Research is moving towards the direct investigation of specific components of eggs in relation to disease risk, however these studies have yet to been performed. Therefore, the conclusions that can currently be drawn is that eggs are a highly bioavailable source of dietary carotenoids and that they are an effective vehicle for increased and site-specific antioxidant uptake in a range of populations.

Conclusions

Dietary carotenoids, including lutein and zeaxanthin, are important antioxidants and are likely to contribute significantly to the body's defence against free-radical attack. As a result, lutein and zeaxanthin may aid in counteracting a number of disease processes, with evidence strongest for a role in decreasing AMD and age-related cataracts. The major sources of lutein and zeaxanthin in the human diet are from fruit and vegetables, however it has been shown that, compared to eggs, the bioavailability of carotenoids from plants may be relatively low. Furthermore, in many populations, the intake of fruit and vegetables has declined. In Australia, the National Nutrition Survey from 1983, 1985 and 1995 identified that between 1983 and 1995, the mean daily intake of fruit decreased by between 30g and 50g for men and women respectively and that the mean daily intake of vegetables decreased by 11g for any population assessed [197]. With its high bioavailability, increased egg consumption would provide a reliable source of dietary carotenoids. Furthermore, substituting a normal egg with a single antioxidant-enriched egg per day would nearly double serum lutein levels. Such an increase may prove to be of significance if additional research into the protective effects of dietary carotenoids against disease is elucidated.

Example key messages:

- Eggs contain the antioxidants lutein and zeaxanthin. Increased intakes of these antioxidants have been associated with eye health and may provide protection against age related eye disease.
- Research indicates that high intakes of antioxidants from spinach, broccoli and eggs are associated with a reduced risk of cataract and age-related macular degeneration.
- The bioavailability of lutein and zeaxanthin is higher from eggs than from other plant sources.
- Eating around one egg a day results in increased antioxidant concentrations in the macular region of the eye. This in turn may be associated with protection from macular degeneration however further research is required to confirm this.
- Eggs contain the amino acids tyrosine and tryptophan which have antioxidant properties.
- Consuming eggs results in higher antioxidant levels in the body.

5. National Nutrition Survey Results

Consumption data from the 1995 National Nutrition Survey showed 16.7% of Australian adults eat eggs, with an average intake of 7.9 grams of egg and 5.8 grams of foods where egg is the major ingredient per day [198]. The 2007 Children's Nutrition Survey showed children and teenagers on average eat 5-11grams of eggs and egg products per day [9]. A further analysis[199] of the Children's Survey provided more insight into egg intake in children (see table below):

	Age group (all children)			
	2-3 years	4-8 years	9-13 years	14-16 years
EGG PRODUCTS AND DISHES (% children consuming per day)	13.9	13.9	11.3	13.8
Eggs (% children consuming per day)	11.3	11.2	9.5	11.4
Dishes Where Egg Is The Major Ingredient (%children consuming per day)	2.9	3.1	1.8	2.7
EGG PRODUCTS AND DISHES (Average grams per day)	6	8.7	7.1	9.4
Eggs (Average grams per day)	4.4	5.6	4.8	5.9
Dishes Where Egg Is The Major Ingredient (Average grams per day)	1.7	3.1	2.3	3.5
Mean portion size of Eggs (consumers only) (grams)	37.2	46.8	46.6	49.4
Median portion size (consumers only) (grams)	37	43	43	43

This section summarises the estimated intake of different fats in the average Australian diet and the contribution of eggs to fat and cholesterol intake and provides a useful introduction to sections 6 and 7.

Table 2: Nutrient Intakes of Australians

Nutrient	Males	Females	Persons
Energy (kilojoules)	11,050	7,481	9,238
Protein (grams)	109.2	73.9	91.2
% energy from protein	17.0	17.2	17.1
Total fat (grams)	98.5	67.6	82.8
% energy from fat	32.4	32.5	32.5
*Recommended %**			*30% for normal weight* *20-25% for overweight people*
Saturated fat (grams)	39.0	26.7	32.7
% energy from saturated fat	12.7	12.7	12.7
*Recommended %**			*<10%*
Monounsaturated fat (grams)	36.2	24.3	30.2
% energy from monounsaturated fat	11.9	11.7	11.8
Polyunsaturated fat (grams)	14.7	10.4	12.5
% energy from polyunsaturated fat	4.9	5.0	5.0
*Recommended %**			*6-8%*
Cholesterol (milligrams)	357.6	239.9	297.9

*As recommended in the Australian Dietary Guidelines for Australian Adults. NHMRC 2003.

Conclusions and example communication messages:

- Australians continue to eat too much total fat and too much saturated fat and do not consume the recommended amounts of polyunsaturated fats.
- While there is no specific Australian recommendation for cholesterol intake, the average intake of cholesterol is within the recommended level of the American Heart Association, which states less than 300mg per day as ideal.
- Between 11-14% of Australian children (2-16 years) consume eggs or egg dishes each day.

Table 3: Contribution of Eggs to Saturated Fat and Cholesterol Intakes versus other Common Foods

Food	Percent contribution to total fat intakes	Percent contribution to saturated fat intakes	Percent contribution to polyunsaturated fat intake	Percent contribution to monounsaturated fat intake	Percent contribution to cholesterol intake
Cereal based products and dishes (biscuits, cakes and mixed dishes)	18.2%	20.3%	15.2%	18%	15%
Milk products and dishes	16.8%	27%	3.8%	12.7%	15.7%
Meat, poultry and game products and dishes	21.8%	20.6%	15.3%	25.7%	37.1%
Fish and seafood products and dishes	2.5%	1.8%	4.4%	2.5%	6.7%
Egg products and dishes	2.0%	1.6%	1.7%	2.4%	16.6%
Eggs alone					11%
Snack foods	1.4%	1.3%	1.2%	1.6%	N/a
Confectionary	2.1%	3.1%	0.8%	1.7%	N/a
Seed and nut products and dishes	2.5%	N/a	4.9%	3.4%	N/a
Fats and oils	11.6%	8.9%	20.5%	12.2%	2.8%

Conclusions and example communication messages:

- The major contributors to saturated fat intake in the Australian diet are milk products and dishes, meat products and dishes and cereal based products and dishes. Eggs contribute comparatively little saturated fat to the average Australian diet.
- Eggs contribute a higher percentage of the healthy monounsaturated type of fat to the diet compared to the unhealthy saturated fats.
- The major contributors to cholesterol intake in the average Australian diet are meat, poultry and game products and dishes, milk products and dishes and cereal based products and dishes. Eggs alone contribute only 11% of the average Australian intake of dietary cholesterol.

6. Scientific Review of Omega-3 Fats and Eggs

The health benefits of foods rich in polyunsaturated fats (PUFAs) and in particular omega-3 fats have been well established. An increased intake of omega-3 fats is now known to protect against heart disease, some inflammatory diseases and certain autoimmune disorders. Omega-3 fats also play a major role in infant growth and development and have been implicated in many other protective roles. The absolute amounts of PUFAs in the diet is important to human health and the balance between the two major types, omega-6 and omega-3, may also be crucial. This section reviews the role of omega-3 fats in health and the contribution of eggs to omega-3 intakes.

6.1 Recommended Dietary Intakes of Polyunsaturated Fats

Health authorities recommend increased consumption of omega-3 fats, namely alpha-linolenic (ALA) and its long chain metabolites eicosapentaenoic acid (EPA), docosapentaenoic acid (DPA) and docosahexaenoic acid (DHA). However, while there is general agreement that omega-3 fats have significant health benefits, there is some variation between the recommendations made by health authorities in relation to adequate and optimal intakes.

ALA is a plant-based fatty acid, found in foods such as walnuts, canola oil, soybeans and eggs, whereas EPA and DHA are mainly present in marine sources (fish, shellfish, marine algae) however recent studies also show the longer chain omega-3 fats are also found in meat and eggs. ALA is metabolised in the body to DHA and EPA however its conversion rate is low. It has been shown that consumption of ALA leads to significant increases in tissue EPA but not DHA, whereas the consumption of fish or fish oil produces higher concentrations of both EPA and DHA [200,201]. This effect limits the extent to which ALA confers health benefits and as a result, the very long chain omega-3 fats DHA and EPA are thought to be the primary mediators of omega-3 health benefits.

In the 2006 update of the NHMRC's Nutrient Reference Values, the first formal recommendations for omega fatty acid consumption in Australia and New Zealand were made. Daily adequate intake (AI) values for linoleic (omega-6), α-linolenic (short chain omega-3) and DHA/EPA/DPA (long chain omega-3) fatty acids are now recommended.

The AI values for dietary fats in Australia are as follows [2]:

	Linoleic (n-6)	**α-linolenic acid (SC omega-3)**	**DHA/EPA/DPA (LC omega-3)**	**Total omega-3**
Men	13g	1.3g	160mg	1.46g
Women	8g	0.8g	90mg	0.89g
Pregnant women	10g	1.0g	115mg	1.115g
Lactation	12g	1.2g	145mg	1.345g

As there is also evidence of the benefits of long chain omega-3 for chronic disease prevention at levels higher than the AI, there is a Suggested Dietary Target (SDT) value for adults:

	DHA/EPA/DPA (LC omega-3)
Men	610mg
Women	430mg

6.2 Australians' intakes of omega-3 fatty acids

Estimations of omega-3 intakes in Australia are reproduced in table 4.

Table 4: Estimated daily Australian intake of omega-3 fats [202]

	Short chain (ALA)	Long chain (DHA/EPA/DPA)	Total omega-3s
Men			
19+ years	1.38g	222mg	1.60g
65+ yrs	1.12g	214mg	1.33g
Women			
19+ years	0.99g	159mg	1.15g
65+ yrs	0.86g	170mg	1.03g

Other figures show that moderate meat-eaters (consuming 260g of meat /day) consumed 1.27g of ALA and 240mg of total long chain PUFA each day. Those that consumed high amounts of meat (>280g meat/day) had a daily ALA intake of 1.96g and 520mg of LC PUFA each day [203]. Ovo-lacto vegetarians consumed approximately 1.42g of ALA each day and the source of a majority of omega-3 fats in this diet were from eggs [203].

A 2006 study also reported similar mean adult intakes of total omega-3 as show in these earlier studies. Total omega-3 intake was found to be 1.31grams, of which LC omega-3s contributed 246mg per day (75mg EPA, 71mg DPA, and 100 mg DHA) [204]. This shows that average omega-3 intakes in Australia do meet the daily Adequate Intake recommendations for general health, however fall short of the Suggested Dietary Targets for chronic disease prevention.

Data from the Blue Mountains Eye Study shows a mean long chain omega-3 intake of 260mg in Australians aged 55 years and over, which is higher than the population mean intake, however still lower than the optimal intake for disease prevention [205].

An analysis of food intake data from the 1995 National Nutrition Survey indicated that seafood was the main source of long chain omega-3 PUFA in the Australian diet, contributing 71%, while meat and eggs contributed 20% and 6%, respectively [202]. These data indicate that there is a need for Australians to increase their daily intake of omega-3-containing foods to meet current recommendations for optimal health.

In individuals who consume very little of the long chain omega-3 fats, the requirement for ALA may be higher. For example, vegetarians who do not consume fish have depressed tissue levels of EPA and DHA [206]. It has been suggested that vegetarians consider using a direct source of DHA (e.g. micro algae) to supplement their diet and/or aim for ALA intakes of 2-4grams per day [206], which is significantly higher than the AI.

For the general population, the NHMRC recommends a moderate increase in intake of sources of omega-3 fats from plant foods (ALA) and from fish (EPA and DHA) to increase the ratio of omega-3/omega-6 fats in the diet and therefore further improve health [207].

Optimal Dietary Ratio of Omega-6 to Omega-3 Fats
The typical Western diet is considered to be imbalanced because it provides high levels of omega-6 and low-levels of omega-3 fats [208]. Omega-6 and omega-3 compete in the body such that high levels of omega-6 block the ability of omega-3 to be used efficiently.

In Australia, a 1992 National Health and Medical Research Council (NHMRC) working party addressed the consumption of omega-3 fats and concluded that the ratio of omega-6/omega-3 in the Australian diet may be as high as 30:1 [207]. Subsequent reports have indicated that this ratio may have declined to a level approaching approximately 10:1 depending on dietary patterns [209-211]. For those who consume meat frequently the ratios are lower at 9.2-9.7:1, whereas ovo-lacto vegetarians or vegans have higher ratios at 12.9:1 and 18.7:1 respectively [203]. In the USA and Northern Europe, the ratio is estimated to be around 15:1 [212,213].

Internationally, the FAO/WHO joint committee recommends an omega-6/omega-3 ratio between 5:1 and 10:1 [214]. Most recently, the Food and Nutrition Board (FNB) of the Institute of Medicine on Dietary Intakes for Energy and Macronutrients established adequate intakes for Americans and Canadians for ALA however did not establish a recommendation about the ratio of omega-6/omega-3 except for pregnant and lactating women where they state that a ratio below 5:1 may be associated with impaired growth in infants [215].

In Australia, although the ratio of omega-6/omega-3 has improved, it is still at an upper acceptable level and further dietary modifications may be appropriate [211]. However, concern about an excessive ratio of omega-6/omega-3 might encourage consumers to reduce their omega-6 intake when the goal is to increase omega-3 intakes. It is considered that even more important than the ratio is the distinction between ALA and the very long chain omega-3 fats in the diet and that the focus of recommendations be on achieving adequate intakes of the latter as the primary mediators of health benefits.

The Omega-3 Index is a relatively new concept used to measure a person's omega status and hence risk towards coronary heart disease mortality [216]. The Index is based on an omega-3 biomarker measured in cell membranes (erythrocyte eicosapentaenoic acid plus docosahexaenoic acid) and having higher levels of this biomarker in the body is thought to reduce the risk for cardiac events. The omega-3 index risk zones are (in percentages of erythrocyte fatty acids): high risk $<4\%$; intermediate risk 4-8%; and low risk $>8\%$. The authors also suggest that lowering omega-6 increases the risk of heart disease, hence the n-6:n-3 ratio shouldn't be used as a predictor in this case. There is therefore some controversy about the application of the omega-6/omega-3 ratio across all disease states.

Overall, there is a need for increasing the intake of omega-3 fats, which will both improve the omega-6/omega-3 ratios and increase absolute intakes towards AI recommendations. The current status of omega-3 consumption and benefits to health will be summarized in the following section.

6.3 Omega-3 Fats and Cardiovascular Health

It has been well established that the consumption of omega-3 fats are important in the prevention and management of cardiovascular disease. In a review of the relationship between dietary fat and cardiovascular disease, the 1999 National Heart Foundation of Australia Position Statement on Dietary Fats [217] concluded that marine omega-3 fats reduce coronary heart events and reduce the risk of coronary death.

The Heart Foundation's 2008 Position Statement on 'Fish, fish oils, n-3 polyunsaturated fatty acids and cardiovascular health' [218] recommends that to lower their risk of coronary heart disease (CHD), all adult Australians should:

1. Consume about 500mg of combined docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) per day through consumption of two or three serves (150 gram serve) of oily fish per week and other foods and drinks enriched with marine n-3 PUFA and/or fish oil capsules or liquid.
2. Consume at least 2 grams per day of alpha-linolenic acid (ALA).

In order to lower their risk of further disease progression, adult Australians with documented CHD are advised to:

1. Consume about 1000 mg per day of combined DHA and EPA through consumption of two or three serves (150 gram serve) of oily fish per week and other foods and drinks enriched with marine n-3 PUFA, and/or fish oil capsules or liquid.
2. Consume at least 2 g per day of ALA.

People with elevated triglyceride (TG) levels are advised to use fish oil capsules or liquid and marine n-3 PUFA enriched foods and drink as a first-line therapy, by starting with a dose of 1200 mg per day of DHA and EPA; and if appropriate increasing the dose to 4000 mg per day of DHA and EPA. It is also recommended their responses be checked every 3 to 4 weeks when the dose is changed, until target TG levels are reached.

Similarly, the American Heart Association recommends that individuals without documented CHD should consume 250-500mg/d mixture of EPA and DHA as either oily fish or fish oil supplements and those with existing heart disease should consume about 1 g/day. People with high triglyceride levels could benefit from 3-4g/d mixture of EPA and DHA. Two oily fish meals per week will provide 400-500mg/d of EPA and DHA therefore supplements are required to achieve higher doses or if fish intake is low. [219] A recent study of over 20,000 adults found daily intakes of EPA and DHA of about 240 milligrams were associated with a 50 per cent reduction in the risk of coronary heart disease, compared with intakes of about 40 milligrams[220].Omega 3 intake has also been linked with a reduced risk of stroke[221]

Although scientific evidence supports a protective effect of omega-3 fats on cardiovascular disease, the possible mechanisms of action have yet to be fully understood. The most recent reviews of the scientific literature suggest that the predominant effect may be anti-arrhythmic [222]. However, omega-3 fats have also been shown to exhibit anti-thrombotic and anti-atherosclerotic effects. Furthermore, omega-3 fats have recognized anti-inflammatory actions that may contribute to their beneficial cardiac effects. Omega-3 fats have also been shown to improve endothelial function, lower heart rate and blood pressure [223,224],decrease plasma triglyceride concentrations [222] and decrease the risk of irregular heart beat (which increases the risk of dying) in men recovering from a heart attack. [225]

A study showed that 960mg/d of EPA and 600mg/d of DHA (long chain omega-3s) can lower CRP levels, a measure of inflammation and risk factor of heart disease[226].
A study in 2009 showed that supplementation with 4 grams of long chain omega-3s per day for 8 weeks improved blood pressure and heart rate in people with kidney disease, a group with a high risk of heart disease [227]

- A study from Denmark showed men (but not women) who had > 390 mg of long chain omega-3 fats had a lower incidence of acute coronary syndrome[228]
- A 2010 review concluded that epidemiological evidence and evidence from clinical trials, indicates that increasing intake and high levels of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) protect from sudden cardiac death and other major adverse cardiac events.[229]

- A recent association study found higher blood levels of ALA and DPA, but not EPA and DHA, to be associated with a decreased risk of heart failure in adults with an average age of 58 years[230].
- A 2012 review of 27 studies (including 251, 049 individuals) found a 14% reduced risk of heart disease with omega 3 ALA exposure[231].

6.4 Omega-3 Fats, Inflammation and Autoimmunity

Inflammation is characterised by pain, swelling and redness to the affected area. In inflammatory joint diseases, this may lead to a progressive loss of cartilage, bone resorption and eventual joint failure. The symptoms of inflammation result from the release of inflammatory mediators that are derived from the omega-6 fatty acid arachidonic acid. These mediators include eicosanoids, prostaglandins, leukotrienes, cytokines, interleukins and tumour necrosis factor. In the modern Western diet, the predominance of omega-6 fats may increase the production of these inflammatory mediators.

It has been well documented that omega-3 fats have anti-inflammatory properties and therefore may be important in the management of inflammatory and autoimmune diseases. Research has demonstrated that omega-3 fats can decrease leukocyte production of omega-6 prostaglandins, leukotrienes as well as cytokines. Furthermore, it has been found that the marine-derived omega-3 fatty acids EPA and DHA are more biologically potent than ALA in their anti-inflammatory responses [232].

Subsequently, the consumption of omega-3 fats has been used successfully in the management of several inflammatory and autoimmune diseases, including rheumatoid arthritis, inflammatory bowel disease (including ulcerative colitis and Crohn’s disease), skin diseases and even migraines. For example, it has been well established that the supplementation of fish oil consistently demonstrates an improvement in symptoms of rheumatoid arthritis and a reduction in the need for non-steroidal anti-inflammatory drugs [233]. In a 2002 review of the preventative and therapeutic effects of dietary omega-3 fats in rheumatoid arthritis, it was noted that doses of up to several grams per day of fish-derived fatty acids may be required [234]. A study in 2009 which looked at 177 people with moderate-to-severe hip or knee osteoarthritis and randomly assigned them to receive either a glucosamine sulfate supplement (1500 milligrams per day) or glucosamine plus omega-3 fatty acids (providing 444 mg of fish oil, of which 200 mg were omega-3-fatty acids). The combination product reduced morning stiffness and pain in the hips and knees by between 48.5 and 55.6 per cent, compared to 41.7 to 55.3 per cent in the glucosamine only group [235]

The therapeutic potential for omega-3 fats in the treatment of inflammatory bowel disease (IBD) has also been demonstrated. Although the causes of IBD are as yet unknown, scientific evidence supports a hypothesis that it may be due to abnormal immunological responses to an altered viral or bacterial antigen. A review of the use of omega-3 fats in the treatment of IBD identified the therapeutic potential for these fats in its treatment. It was concluded that fish-derived fatty acids might act by reducing low-grade active inflammation [236]. However, it has not been determined whether this treatment is applicable to all individuals with IBD and appropriate doses of omega-3 fats have yet to be characterized.
A recent study also looked at the anti-inflammatory properties of egg white peptides (protein) in a pig model with intestinal inflammation. Results showed that supplementation with egg white peptides had a favourable effect on the immune system and the symptoms of inflammation.[237]

In conclusion, although the potential for the use of omega-3 fats in the management of inflammatory and autoimmune diseases is very high, further studies are required to establish safe and adequate omega-3 fat intakes.

6.5 Omega 3 Fats in Pregnancy and Neonatal Development

Long chain omega-3 fats are known to be rapidly incorporated into the lipids of the brain and retina during the last trimester of pregnancy and during the first year of life. It is now widely recognized that omega-3 fats, particularly DHA, are required for the optimal development of the nervous system and maturation of visual acuity in preterm and term infants [238]. There is also evidence to suggest that the intake of omega-3 fats during pregnancy may play an important and modifiable role in gestational duration and parturition. The supplementation of DHA during pregnancy may be useful in prolonging the duration of gestation in some high-risk pregnancies. Birth weight and age are critical determinants of infant health. DHA supplementation during the last trimester has also been shown to improve an infant's cognitive development [239]. Furthermore, consumption of long chain omega 3s (as fish oil) during pregnancy and the early stages of breast feeding has been shown to lower the risk of food allergies and eczema [240]Independent of their effects on the duration of gestation, the additional supplementation of omega-3 fats in the diet of pregnant women has been recommended in respect to neonatal development [241].

The 1999 Workshop on the Essentiality of and Recommended Dietary Intakes for Omega-6 and Omega-3 Fatty Acids recommended that, for pregnancy and lactation, women should ensure a DHA intake of 300mg per day [241]. This is in comparison to the recent Australian AI of 115mg and 145mg respectively for total long chain omega-3 during pregnancy and lactation [2]. Although the optimal fatty acid composition of infant formula has not yet been determined, it is considered that they should be designed to approximate the fatty acid composition of breast milk and therefore should include omega-3 fats. The above-mentioned 1999 Workshop suggests that for infant formula/diet, the Adequate Intake (AI) of DHA should comprise of 0.35% of fatty acids in the formula.

6.6 Other Potential Benefits of Omega-3 Fats

Current evidence suggests long chain omega-3 fatty acids, particularly DHA, may be beneficial for bone health. Studies in ovarectomised rats have shown DHA supplementation can slow the rate of bone loss [242,243] and higher intakes of long chain omega-3s have been positively associated with bone mineral density (BMD) in adults [244,245]. Omega-3 fatty acids may also assist with bone accretion with higher levels of plasma DHA having been linked to both total and spinal BMD in boys aged between 16 and 22 years of age [246].

- Omega-3s may also play a role in maintaining normal mental function. In adults, higher intakes of omega-3s [247] as well as higher plasma levels [248] have been linked to slower cognitive decline, lower rates of depression [249], reduced risk of dementia [250]and a greater sense of physical well-being [251]. In adolescents lower blood cell levels of EPA and DHA have been linked with depression[252]. Eating long chain omega 3s (in particular DHA) has also been associated with better memory and learning in healthy older people [253]Children with Attention Deficit Hyperactivity Disorder (ADHD) may also benefit from consuming additional long chain omega-3s. Significant improvements in behaviour were seen in children with ADHD taking 16.2g EPA and DHA every day for 8 weeks [254]. Higher levels of long chain omega 3 levels have been associated with lower body fat levels in healthy individuals ([255]. It has also been shown that infertile men have lower levels of long chain omega-3s in their blood and sperm than fertile men [256].

- A study which analysed 12 years of prospective data from 70,709 women in the Nurses' Health Study, found that while overall fat consumption was not linked to the risk of endometriosis, specific fat types did have an impact. Women with high intakes of trans fats were significantly more likely to suffer from endometriosis than women with lower intakes, while increased intakes of omega-3 fatty acids may decrease the risk by 22 per cent.[257]
- Another study examined the effects of omega-3 supplementation (1000 mg/day for 12 weeks) on 40 healthy young wrestler's lung function during intensive wrestling training. The results found that consuming omega-3 during intensive wrestling training may improve lung function of athletes during and after exercise.[258]
- Omega 3 intake has been associated with a decreased risk of diabetes[259].
- A study has found regular consumption of omega-3 is associated with a reduced risk of age-related macular degeneration in women[260]. A review has also confirmed that omega 3 EPA and DHA are essential for eye health[162].
- Low omega 3 intake has been linked with smaller brain size and cognitive impairment[261]

6.7 Omega-3 Fats in Eggs and Health Benefits

Eggs provide omega-3 fatty acids, contributing an average of 180mg per serve, 12% of the omega-3 AI recommendation for men and 20% for women [2]. Of this, 114mg is long chain omega-3 fatty acids, representing 71-127% of the long chain omega-3 AI. Eggs are therefore a particularly useful source of long chain omega-3 fatty acids for ovo-vegetarians and others who do not eat fish regularly.

It is also well known that the composition of the fatty acids in egg yolks can be altered. For example, Belovo SA (Belgium) has designed an egg containing increased levels of omega-3 fats. Marketed in the USA as the Christopher Egg and in Europe as the Columbus Egg, this modified egg contains 660mg of omega-3 fats per 50g edible portion, of which 550mg is ALA, 10mg is EPA and 80mg is DHA [262]. The increased levels of omega-3 fats in this egg not only increase its DHA content to nutritionally significant levels but also create a balanced 1:1 ratio with omega-6 fats. In Australia, an omega-3 enriched egg has been developed by feeding poultry a stabilized tuna fishmeal product PorcOmega (POM). The total long chain omega-3 content increased 4-fold in eggs of laying chickens fed POM [263]. Flaxseed can also be included in the poultry feed to increase the omega-3 content. The Body Egg, produced by Chanteclair and Pace Farm, provides 905mg omega-3 from ALA and 208mg omega-3 from DHA, EPA and DPA providing a total of 1113mg omega-3 per 104g (2 standard eggs). Farm Pride has also launched free range, omega-3 enriched eggs onto the Australian market. The eggs come from chickens that are fed a natural grain diet fortified with omega-3. The omega-3 content is more than twice that found in standard eggs. Research has also found chia seeds to be an effective way of increasing the omega-3 content of eggs [264]. Feeding hens with chia seed or chia oil yielded more omega 3 per gram of egg yolk compared to feeding flaxseed.

The cholesterol content of omega-3 enriched eggs is no greater than a standard egg. In fact, the Columbus egg contains 10-20% less cholesterol than a standard egg, containing approximately 220mg cholesterol per egg.

Researchers in France have designed eggs enriched with linseed, minerals, vitamins and lutein (Benefic(R) eggs) in the last several years. These eggs were found to contain 6 times more ALA, vitamin E and lutein and zeaxanthin, 4 times more folic acid and selenium, 3 times more DHA and vitamin D, and 2.5 times more iodine compared to standard eggs. However the omega-6 fatty acid content was kept constant to favourably lower the omega-6/omega-3 ratio [265].

The incorporation of omega-3 enriched eggs in the Australian diet may provide an appropriate vehicle for further increasing omega-3 fat consumption. Table 5 highlights the fatty acid composition of Australian eggs.

Table 5: Fatty acid composition of Australian eggs

Fatty acid subtype	Fatty acid profile (% total)	Fatty acid content (g/100g)
Oleic acid	44	4.37
Linoleic acid	11.4	1.13
Alpha linolenic acid	0.6	0.06
Arachidonic acid	1.8	0.18
DHA	1.0	0.1
DPA	0.1	0.01
EPA	0	0
Total monounsaturated	50.9	5.1
Total polyunsaturated	15.6	1.6
Total saturated	33.3	3.3
Total omega-3	1.7	0.17
Total omega-6	13.8	1.37

Studies have shown that omega-3 enriched eggs may confer health benefits, particularly for blood lipid profiles and for infants.

6.7.1 Effect of enriched egg consumption on blood lipid profiles

A 2007 study showed that among 25 healthy participants, consumption of five omega-3 enriched eggs a day for three weeks was associated with a significant 16-18% decrease in serum triglycerides compared to regular eggs [266]. This finding supports previous research in this area. Jiang and Sim [267] studied the effects of omega-3 enriched eggs on the lipid status of healthy males. The supplementation of two omega-3 enriched eggs per day for eighteen days significantly increased HDL cholesterol levels and significantly decreased LDL cholesterol levels, compared to control subjects consuming two standard eggs per day [267]. The plasma fatty acid composition of subjects consuming two enriched eggs per day also exhibited a moderate increase in omega-3 content. In a study of mildly hyper-triglyceridaemic men supplementing their diet with ten DHA-enriched eggs per week, serum triglycerides and HDL-cholesterol levels were significantly reduced when compared to baseline [268]. Conversely, in a study of individuals consuming only one omega-3 enriched egg per day (DHA/EPA and ALA), no differences in plasma lipid components were observed among treatment groups, however significant increases in plasma EPA, DHA and total omega-3 fats were observed in the treatment groups [269]. Similar data was observed in another study whereby consumption of one DHA-enriched egg per week increased plasma DHA levels but no changes were observed in plasma lipid components [145]

Two unpublished studies have investigated the effects of substituting Columbus eggs for standard eggs. In a study of post-menopausal women, the intake of 1.13 Columbus eggs in place of 0.65 standard eggs per day had no effects on total cholesterol, HDL or LDL cholesterol, but plasma triglycerides were significantly reduced by 9.6% [262]. A second study of hypercholesterolaemic individuals showed consumption of four Columbus eggs/week resulted in an 18% reduction in triglycerides, a slight decrease in total cholesterol and no change in HDL or LDL cholesterol levels [270].

6.7.2 Effect of enriched eggs on infants

Including omega-3 enriched eggs in the weaning diets of infants may offer significant benefits. DHA is important for proper neurological development [271] and may also play an important role in cognitive function in infants [272]. One well controlled trial undertaken in South Australia [113] showed the inclusion of four omega-3 enriched egg yolks a week in the diets of infants aged 6-12 months resulted in red blood cell concentrations of DHA that were 30-40% higher compared with infants fed no eggs or standard egg yolks. A major finding was that infants fed formula without DHA but who consumed four omega-3 egg yolks had red blood cell DHA percentages that were not significantly different to breast fed infants. It was concluded that eggs enriched with omega-3 provide a means of increasing DHA in the diet during the second 6 months of life without altering plasma cholesterol. This in turn may have significant benefits for development of visual acuity and neurological developmental outcomes. This research has also been supported with the results of an American study that fed one group of infants baby food enriched with egg yolk and DHA between 6-12 months of age and compared this to a group of control infants receiving baby food alone [273]. At the end of the six month intervention, visual acuity was significantly better in the infants receiving egg yolk and DHA.

Another recent study investigated the relationship between maternal DHA levels at birth and attentiveness of toddlers into their second year. Toddler attentiveness was assessed at 12 and 18 months. Toddlers of mothers who received high DHA eggs (135mg DHA) during pregnancy were more attentive than toddlers of mothers given low (35mg) DHA eggs These findings are consistent with evidence suggesting a link between DHA and cognitive development in infancy and early childhood [274]

In summary, many Australians fall short of the omega-3 recommendations for chronic disease prevention. Although fish is recommended as the key dietary strategy for people to increase their omega-3 intake, modern Western societies generally consume inadequate amounts of fish and therefore this dietary approach alone may not be an effective way to achieve an increase in the consumption of omega-3 fats. Standard eggs provide 12-20% of the omega-3 AI for adults and 14-33% AI for children, making them a useful source of this essential fatty acid in the diets of Australians. Their content of long chain omega-3s (71-127% AI for adults) provides further benefits for ovo-vegetarians and those who do not eat fish regularly. Omega-3 enriched eggs, which contain up to five times more omega-3s than standard eggs, may provide an even greater mechanism for increasing omega-3 fat consumption in Australia.

Example key messages:

- The average intake of omega-3 fats in Australia is well below the levels recommended for preventing chronic disease. Most Australians would benefit from increasing their intake of omega-3 fats.
- Eggs contain useful amounts of the long chain omega-3 fatty acids.
- Omega-3 fats provide heart health benefits and have anti-inflammatory properties.
- Including omega-3 enriched eggs in the diet improves omega-3 levels in the body, which in turn may have significant health benefits.
- Including omega-3 enriched eggs in the diets of infants may improve omega-3 status in the body, which in turn has significant developmental benefits.
- Vegetarian diets are relatively low in omega-3 fats. Due to their range of health benefits, vegetarians may particularly benefit from increasing food sources of omega-3 fats in their diet, such as eggs.

7. Scientific Review of Cholesterol, Eggs and Cardiovascular Disease

The following section provides an overview of the findings from scientific research and reviews regarding cholesterol, eggs and cardiovascular disease. This section covers the following key areas:

- Dietary cholesterol and plasma cholesterol
- Hyper-responders and hypo-responders of dietary cholesterol
- Dietary cholesterol and coronary heart disease risk
- Egg consumption and:
    - blood cholesterol studies
    - hypo- and hyper-responders
    - coronary heart disease risk
    - interpretation of the evidence.

Introduction

The relationship between dietary fat intake and cardiovascular disease (CVD), which includes coronary heart disease (CHD), myocardial infarction (MI) and stroke, has been well established. Substantial scientific evidence has already identified that the types of fat is more important than the total amount of fat in determining CVD risk. The National Heart Foundation of Australia's 2009 Position Statement on Dietary Fats [31] extensively reviewed this literature and summarized the following associations:

- increased consumption of saturated fatty acids is associated with an increased risk of CHD
- *trans* fatty acids increase the risk of CHD particularly at high levels of intake
- increased consumption of saturated and *trans* fatty acids, rather than total fat, increases the risk of CHD
- replacement of saturated fatty acids with omega-6 polyunsaturated fatty acids reduces the risk of coronary events and deaths
- marine and plant omega-3 polyunsaturated fatty acids reduce coronary heart events.

A recent report published by the Australian Institute of Health and Welfare in June 2012 reported that approximately 1.6 million men and 1.8 million women were estimated to have cardiovascular disease in 2007-2008[275]. Between 1968 and 2009, however, the death rate from CVD has fallen by 78%[275]. Coronary heart disease (CHD) remains the largest single cause of death in Australia (accounting for 16% of all deaths) in 2009. The death rate for CHD is also declining however the rates of decline are not consistent across all age groups.

For CHD mortality:

- Recent declines have been greatest among people aged 55–74 years
- The average annual rate of decline has accelerated among older people (65 years and over)
- The rate of decline for CHD has levelled off among younger people (aged 35–54 years)
- The rate of decline for stroke has slowed among younger women (aged 35–54 years).

Despite the falls observed, death rates from CHD remain higher than those in many other developed countries, indicating the potential for further declines. The situation is similar for stroke.[276]

With respect to cholesterol, the latest position statement from the National Heart Foundation states there is inconclusive evidence supporting a relationship between dietary cholesterol and CVD outcomes[31].Furthermore dietary cholesterol raises cholesterol and total cholesterol levels but substantially less than saturated and trans fats[31]. Of relevance to this point is additional research that has found a 30% decrease in saturated fat intake would reduce blood cholesterol by 9.6mg/dL (0.244mmol/L) compared to a 100mg decrease in cholesterol which would result in a 2.2-2.6mg/dL (0.056-0.066mmol/L) decrease [277,278]. A 100mg decrease in cholesterol would represent approximately a 30% decrease in the average Australian intake of cholesterol. In summary, a reduction of saturated fat is approximately four times as effective at lowering blood cholesterol levels compared to a similar degree of reduction in dietary cholesterol intake. A study published in the American Journal of Clinical Nutrition, analysed eight trials, which provided data on 13,614 participants and 1,042 coronary heart disease events. The results provided conclusive evidence that people who replaced saturated fat in their diet with polyunsaturated fat reduced their risk of coronary heart disease by 19 percent, compared with control groups of people who did not change their diet. The article emphasised that reducing saturated fat does not bring on this benefit per se, but what it is replaced with is most important in relation to health benefits. The results suggest that polyunsaturated fats would be a preferred replacement for saturated fats as a way of improving heart health [279] The following section explores this issue further.

7.1 Dietary Cholesterol and Plasma Cholesterol

It has long been assumed that increased dietary cholesterol intake leads to high blood cholesterol, which in turn raises CHD risk. However, cholesterol in the diet is not the principal factor affecting the level of cholesterol in the bloodstream. The main dietary determinants of plasma cholesterol are saturated fat and *trans* fat intake [31,280]. Cholesterol in the blood comes from both that which is made in the liver and that which is absorbed from dietary sources. In most instances, when dietary cholesterol intake increases, the body compensates by decreasing cholesterol production. When cholesterol intake decreases the reverse occurs. This compensatory mechanism has been proposed to be the predominant reason why changes in dietary cholesterol intake may have only a limited effect on blood cholesterol levels [280]. Although numerous clinical studies have shown that dietary cholesterol challenges may increase LDL cholesterol in certain individuals, who are more sensitive to dietary cholesterol (about one-quarter of the population), HDL cholesterol also rises resulting in the maintenance of the LDL/HDL cholesterol ratio, a key marker of coronary heart disease risk[281]. Furthermore numerous studies have shown dietary cholesterol increases LDL particle size and alters the number of large and small LDL particles[282,283]. This type of cholesterol profile is associated with a decreased risk for heart disease. Several studies have also shown that dietary cholesterol intake promotes the formation of larger HDL particles.

The extent of plasma cholesterol responses to changes in dietary cholesterol have been the source of much debate, however studies performed since 1996 have confirmed and strengthened the conclusions that dietary cholesterol has only a small effect on blood cholesterol.

In a meta-analysis of 224 published studies of 8,143 subjects in 366 independent groups, including 878 diet-blood lipid comparisons, the predicted plasma cholesterol response to a 100mg/day change (decrease) in dietary cholesterol was 2.2mg/dL (0.056mmol/L), or approximately 1% in the average population cholesterol concentration [278]. The findings of this study were supported by another meta-analysis involving 395 dietary experiments among 129 groups of individuals. In this analysis it was identified that a 100mg decrease in dietary cholesterol corresponded to a 2.5mg/dL (0.063mmol/L) decrease, on average, in plasma cholesterol [277].

In an analysis involving 167 published cholesterol feeding studies in 3,519 subjects dating back to 1960, it was identified that plasma cholesterol levels do increase as dietary cholesterol increases [284]. This analysis included various patient types such as people with normal cholesterol levels as well as those with high cholesterol levels, young to elderly, and male and female subjects. The studies included differing conditions, a wide range of background diets and dietary cholesterol intakes ranging from physiological doses (100-300mg) to pharmacological doses (3-5g). Of the 167 studies, 153 were used in a meta-analysis. A dose adjusted plasma cholesterol response of 2.2mg/dL (0.056mmol/L) per 100mg/day change (increase) in dietary cholesterol was identified [284]. Thus, the change in cholesterol levels is minor. When dietary cholesterol is taken in, the body compensates by making less. This mechanism, along with the fact that only 60% of dietary cholesterol is absorbed, may be interpreted that a change in dietary cholesterol of 100mg/day results is an actual change in cholesterol metabolism of 30mg/day, which is less than 3% of the total mass of cholesterol metabolised daily in the body [284].

The meta-analysis performed by Clarke *et al* [277] identified that dietary cholesterol increased plasma total cholesterol by increasing both the 'bad' LDL-cholesterol and the 'good' HDL-cholesterol [277]. In this study it was estimated that a 100mg/day change (decrease) in dietary cholesterol would result in a corresponding change of approximately 1.9mg/dL (0.048mmol/L) LDL-cholesterol and 0.4mg/dL (0.01mmol/L) change in HDL-cholesterol [277]. McNamara [284] further supported these findings. In a similar analysis, the estimated responses to a 100mg/day change in dietary cholesterol were 2.07mg/dL (0.052mmol/L) for LDL-cholesterol and 0.44mg/dL (0.011mmol/L) for HDL-cholesterol [284].

A study found that cholesterol absorption was highest in lean insulin sensitive participants whereas cholesterol synthesis was highest in lean insulin resistant and obese insulin resistant subjects. The authors suggest that for lean insulin-sensitive subjects a low intake of dietary cholesterol should be emphasized but the focus for insulin resistant individuals should be weight loss to decrease cholesterol overproduction by the body[285].

These studies demonstrate that dietary cholesterol does have a measurable but small effect on plasma cholesterol levels and that the increase in plasma total cholesterol results from increases in both LDL-cholesterol and HDL-cholesterol levels. HDL cholesterol is an independent risk factor for cardiovascular disease and higher levels are found to be cardio-protective[286]. Emerging evidence reveals many protective functions of HDL-cholesterol and therefore its importance in relation to cardiovascular disease should not be understated[286]. There remains much debate about dietary cholesterol's role on blood cholesterol levels and subsequent heart disease risk[283]. However, the most important message to reduce blood cholesterol levels is to encourage people to quit smoking, increase physical activity and reduce saturated fat intake [287].

Further to studies on dietary cholesterol impacting cholesterol levels, a study has found that the intake of dietary cholesterol increases the risk of stroke[276]

Example key messages:

- Dietary cholesterol is not the main determinant of blood cholesterol levels.
- When cholesterol is taken in from food, the body balances the level in the blood by making less.
- Increasing dietary cholesterol intake results in a small increase in blood cholesterol levels. Of the small increase, around 25% is due to an increase in the 'good' HDL cholesterol level.
- Dietary cholesterol intake maintains the LDL:HDL ratio. The LDL:HDL ratio is a key marker of coronary heart disease risk.
- Dietary cholesterol intake alters the size of cholesterol particles in the body which may favourably effect heart disease risk.

7.2 Hyper- and Hypo-Responders to Dietary Cholesterol

Variability in the responsiveness of plasma cholesterol to dietary cholesterol has been established and numerous studies have identified that there are both cholesterol sensitive and cholesterol resistant individuals [288-291]. The response to dietary cholesterol has also been shown to be somewhat reproducible within a subject [290].

It has been estimated that between 15-25% of the population is sensitive to dietary cholesterol [284]. The data from all the meta-analyses previously described in this review only represent the average plasma cholesterol responses predicted for changes in dietary cholesterol. In a re-analysis of his own study, McNamara [284] identified that the dose-adjusted response to a 100mg/day dietary cholesterol challenge in hyper-responders is 3.9 +/- 0.6 mg/dL (0.099 +/- 0.015 mmol/L) compared to a response of 1.4 +/-0.2 mg/dL (0.035 +/- 0.005mmol/L) in hypo-responders, representing almost a 3-fold difference. The LDL-cholesterol response was the predominant lipoprotein response to dietary cholesterol, particularly in hyper-responders. The meta-analysis performed by Howell *et al* [278] also identified a large range of variability between individuals in response to changes in dietary cholesterol. It used to be thought that people with hyperlipidaemia were more likely to be hyper-responders and that restriction of dietary cholesterol intake was therefore prudent in this group. However, research shows that despite hyper-responders experiencing an almost three fold greater response to dietary cholesterol compared to the remainder of the population [284], the LDL:HDL ratio is not significantly changed [292-294]. How these findings translate to changes in cardiovascular disease risk remains to be shown by randomised controlled trials.

The factors determining why variations in the plasma cholesterol response to dietary changes exist have yet to be identified, but body weight and blood lipid profiles have been suggested as potential contributors. Furthermore, the existence of consistent hypo- and hyper-responders also supports a hypothesis that responsiveness may be related to genetic variation.

One study has identified that excess body weight is associated with a decreased sensitivity to dietary cholesterol [295]. The Chicago Western Electric Study, a prospective cohort study of 1,903 middle-aged men, showed the dose-adjusted plasma cholesterol response to dietary cholesterol was greater in individuals with a body mass index (BMI) less than 24.2kg/m^2 when compared to individuals with a higher BMI (> 26.6 g/m^2) [295]. As suggested by McNamara [284], this association may be due to liver production of cholesterol being a function of body weight. Thus, it may be predicted that individuals with a low BMI would have lower rates of cholesterol synthesis and reduced feedback regulatory responses. In the meta-analysis of plasma cholesterol response to dietary cholesterol performed by McNamara [284], plasma cholesterol responses did not differ between hypo- and hypercholesterolaemic subjects. Based on these findings the author concluded there was no evidence to suggest that individuals with elevated plasma cholesterol would be more sensitive to the plasma cholesterol raising effects of dietary cholesterol. A large number of studies have investigated whether the heterogeneity in responsiveness to changes in dietary lipids intake may be explained by variations in candidate genes such as those whose products affect lipoprotein metabolism. In a systematic review from 74 related articles, Masson *et al* [296] found evidence to suggest that variations in the genes for certain apolipoproteins contribute to the heterogeneity in the lipid response to dietary intervention. However, the effects of genetic variation were not consistently observed and conflicting data was reported.

In summary, considerable heterogeneity of cholesterol responses exist between individuals, with up to 85% of people being classified as hypo-responders. In response to dietary cholesterol, increases in plasma total cholesterol were observed for both hyper- and hypo-responders. Both LDL-cholesterol and HDL-cholesterol concentrations were increased, but the LDL-cholesterol increase was greater in the hyper-responders.

Example key messages:

- People vary in their responses to increases in dietary cholesterol intake. A 100mg per day increase in dietary cholesterol can result in a three times greater effect on blood cholesterol levels in sensitive people compared to non-sensitive people.
- The differences in individual responses to changes in dietary cholesterol intake may be due to genetics.
- Up to 85% of the population may be non-sensitive to changes in dietary cholesterol intake.

7.3 Dietary Cholesterol and Coronary Heart Disease Risk

Early population based studies aimed at finding the risk factors for CHD identified elevated blood cholesterol as an important determinant of disease risk [297,298]. It was anticipated that dietary changes aimed at lowering blood cholesterol levels would help to reduce the incidence of CHD. Subsequently, feeding studies identified that dietary saturated fats increased blood cholesterol levels and polyunsaturated fats decreased cholesterol levels [299,300]. It has however been established recently that different types of saturated fats affect cholesterol levels differently and that the effect of particular foods on coronary heart disease risk cannot be solely predicted based on saturated fat levels[301].

Early epidemiological studies also identified dietary cholesterol as having cholesterol raising effects, however data from subsequent population based surveys has identified only a weak positive relationship between dietary cholesterol and CHD risk. Furthermore, this association is often lost when the data is statistically adjusted to remove other factors that could be contributing to confounding the results. For example, in one study, dietary cholesterol intake was measured in a group of 871 middle-aged men. After a 10-year follow-up, intake of dietary cholesterol was not significantly related to coronary death, but at 20 years a positive association was observed [302]. After taking into account the established risk factors for CHD, the association was found to be not significant [302].

In a 16-year follow up of 813 men, initially disease free, 123 individuals developed coronary disease. After adjustment for multiple confounders, no significant relationship was observed between dietary cholesterol and CHD risk [303]. A study of 4,546 men and women with a 12-year follow-up identified no association of dietary cholesterol and increased death risk after taking into account energy intake and other risk factors for CHD [304]. In a large study of 80,082 nurses, a 14-year follow-up identified 939 cases of coronary heart disease [305]. After accounting for multiple confounders including saturated, polyunsaturated, mono and *trans* fats, dietary cholesterol was positively associated with CHD risk but the relationship was not statistically significant [305]. It must be noted that fibre was not included as a confounder in this study even though fibre has been associated with reduced CHD disease risk. Therefore, the strength of this association may have been even further weakened had this confounder been included in the analyses. However, in a 2004 study from this same cohort that assessed the effect of dietary fat and cholesterol on the risk of CHD among women with type 2 diabetes, it was found that an increase of 200mg cholesterol/1000kcalorie resulted in a 37% increase in risk [306].

In another large study of 43,757 men with up to a 6-year follow up, no significant association was observed between cholesterol intake and mortality from CVD after adjusting for multiple risk factors including dietary fat and fibre intake [307]. As commented by Kritchevsky *et al* [308], the data presented from this study emphasises the importance of adjusting for other dietary factors. When fat and fibre were not accounted for, the apparent relative risk associated with increased dietary cholesterol was shown to be four times larger than it was after these factors were included in the statistical test.

In a 10-year follow-up study of over 8,000 men initially free of cardiovascular disease, 456 individuals developed CHD. Cholesterol intake was significantly associated with an increased risk of disease after adjusting for age, blood pressure, serum cholesterol, smoking, body weight and physical activity [309]. However, dietary fat and fibre were not included in the analyses so the significance of this association may again be questioned.

In a review of dietary cholesterol intake and CHD risk, McNamara [284] supported the argument that questions the positive association described between dietary cholesterol consumption and CHD risk. McNamara reinforced the observations that early studies establishing the link between dietary cholesterol and CHD risk were frequently based on simple statistical analysis and therefore did not take into consideration potential confounders such as saturated fat and fibre intake. He also identified more recent population based studies that used more advanced statistical analyses to account for these confounders, which resulted in dietary cholesterol no longer being associated with CHD mortality. In addition to the population studies described in this review, McNamara further identified a number of prospective studies that have reported no relationship between dietary cholesterol and CHD endpoints when more advanced statistical analyses were used [305,307,310,311]. Although some researchers have interpreted these newer statistical analyses as confirmation that little or no relationship exists between dietary cholesterol and CHD risk, this viewpoint is still under considerable debate.

Interestingly, there is some (but at this stage limited) evidence that remnant cholesterol (the cholesterol content of the triglyceride-rich lipoproteins known as very low-density lipoproteins and intermediate-density lipoproteins together with chylomicron remnants (the amount of cholesterol remaining when HDL and LDL cholesterol are taken away from total cholesterol level)), may be a causal risk factor for ischemic heart disease. Further research is needed to understand this possible link[312].

In conclusion, it can be stated that although an association between dietary cholesterol and CHD mortality has been described, considerable argument still exists regarding the basis and strength of this relationship.

Example key message:

- Recent population studies show little or no associations between cholesterol intake and risk of heart disease.

7.4 Egg Consumption and Blood Cholesterol Studies

Research conducted over the past 50 years shows egg consumption has only a small effect on raising total plasma cholesterol levels in most healthy people. Three meta-analyses have been conducted investigating the effects of eggs or dietary cholesterol on serum cholesterol levels.

The most recent meta-analysis of 17 human experimental studies published in 2001 found on average, increasing dietary cholesterol from eggs by 100mg daily, equivalent to half a 60gram egg or 3-4 eggs a week, results in the serum lipid changes shown in Table 6 [313].

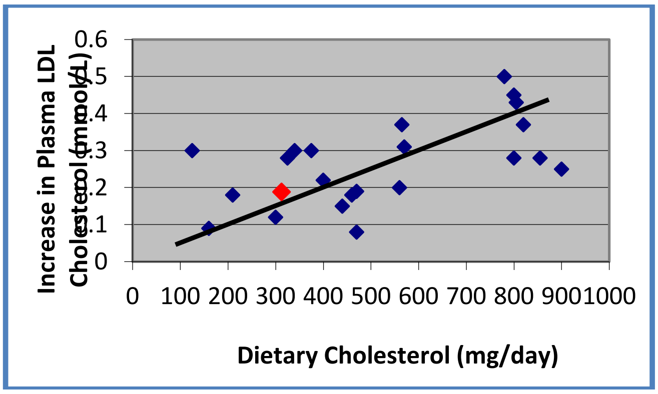
Table 6: Predicted changes in serum total cholesterol concentration, induced by a 100mg/day increase in dietary cholesterol from eggs alone [313]

Serum cholesterol concentration	Predicted change (95% CI)
Total cholesterol (mmol/L)	0.056 +/-0.005 (0.046, 0.065)
HDL cholesterol (mmol/L)	0.008 +/- 0.001 (0.005, 0.010)
LDL cholesterol (mmol/L)	0.050 +/- 0.004 (0.042, 0.058)

These results are consistent with a meta-analysis on the plasma lipid and lipoprotein responses to dietary fat and cholesterol published in 1997 showing a 100mg decrease in dietary cholesterol results in a 0.057mmol/L decrease in plasma cholesterol translating to an approximate 1% decrease in the average population cholesterol concentration [278].

A third meta-analysis of the effects of dietary cholesterol on serum cholesterol found higher baseline intakes of dietary cholesterol attenuated the increase in serum cholesterol seen with increasing intakes [314]. However, subsequent studies have shown this occurs only at baseline cholesterol intakes greater than 1,000 – 1,200mg per day [284,315]. While the predicted changes in serum cholesterol induced by a 100mg per day increase in dietary cholesterol from eggs would be expected to diminish with higher baseline intakes, only three of the 17 studies included in the Weggemans et al meta-analysis involved subjects with a cholesterol intake greater than 1,000mg daily. Linear regression models were therefore used in the analysis showing the following serum LDL changes with increasing dietary cholesterol intake up to 1,000mg a day (Figure 1).

Figure 1: Predicted changes in serum LDL cholesterol induced by a 100mg/day increase in dietary cholesterol from eggs alone [313]



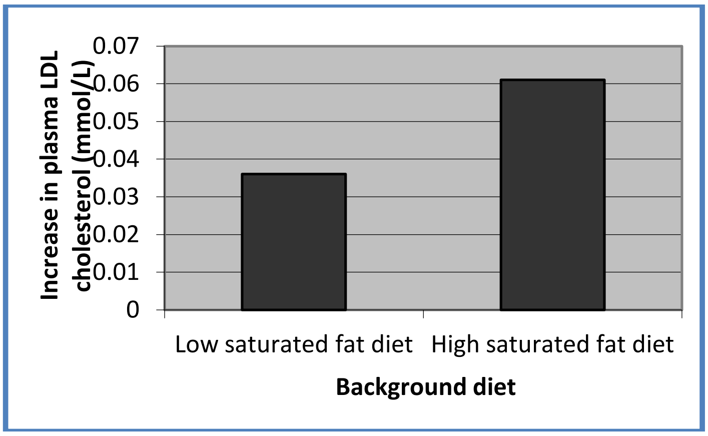
The red diamond indicates the average Australian intake of cholesterol from the 1995 National Nutrition Survey (297.9milligrams).

In the Weggemans et al meta-analysis, all experimental studies on eggs, total cholesterol and lipoproteins conducted since 1989 that met strict inclusion criteria were reviewed. Inclusion criteria were that the study was published in English; within a study, the composition of the experimental diets could differ only by the amount of eggs; subjects had to be weight stable throughout the study; the design had to eliminate the effect of non-specific drifts of the outcome variable with time; feeding periods had to be greater than 14 days; and studies had to report fasting concentrations of cholesterol and lipoproteins.

The changes in plasma cholesterol levels outlined in Table 6 and Figure 1 represent maximal estimates because the increase in plasma LDL cholesterol in response to increased egg consumption is attenuated when the background diet is low in saturated fat [316]. This finding was confirmed in the meta-analysis when studies were divided into two groups: those with a background diet relatively high in saturated fat, and those with a background diet relatively low in saturated fat. As demonstrated in Figure 2, adding 100mg of cholesterol to a high saturated fat diet caused an increase in LDL cholesterol of 0.061 +/- 0.006mmol/L, whereas adding the same quantity of cholesterol to a low saturated fat diet caused an increase in LDL cholesterol of only 0.036 +/-0.004mmol/L. The effect on LDL cholesterol from an increase in dietary cholesterol from eggs is therefore 1.7 times greater when the background diet is high in saturated fat compared to a low saturated fat background diet. This finding reinforces the recommendations from heart associations worldwide to reduce dietary saturated fat as a key strategy for reducing serum cholesterol levels.

This is due to the significant impact dietary saturated fat has on serum cholesterol levels with research showing that for every 1% increase in total daily kilojoules from saturated fatty acids, serum LDL cholesterol rises by about 2% [317]. Furthermore, a recent study in people with diabetes found that when subjects consumed 2 eggs per day verus 100g of lean animal protein there was no difference in LDL cholesterol but HDL cholesterol increased in the egg group[318].

Figure 2: Change in LDL cholesterol with an additional 100mg dietary cholesterol from eggs (independent of saturated fat)



The Weggemans et al study also showed a small increase in HDL cholesterol with increasing cholesterol intake from eggs. The National Heart Foundation of Australia [319] and the American Heart Association [320] recognise low HDL as a major risk factor for coronary heart disease.

Overall, the increase in total and LDL cholesterol levels seen with increased dietary cholesterol intake from eggs is small, however it is greater when the background diet is high in saturated fat. Therefore, based on the impact of dietary cholesterol from eggs on plasma cholesterol levels, there is insufficient evidence to restrict egg consumption in healthy people following a low saturated fat diet.

A number of additional studies have been conducted examining the relationship between egg consumption and serum cholesterol concentrations. A study in Sprague-Dawley rats fed an egg-enriched diet had lower blood levels of triglycerides (a fat in the blood), total cholesterol, low density lipoprotein (LDL)-cholesterol, levels of triglyceride and cholesterol in the liver and greater blood levels of high-density lipoprotein cholesterol concentration than those fed a plain cholesterol diet[321].

A large study conducted in 2000 used data from 27,378 individuals obtained from the National Health and Nutritional Examination Survey (NHANES III 1988-94)[322]. In this study, individuals who reported eating 4 or more eggs/weeks had a significantly lower mean cholesterol concentration than those who reported eating less than one egg/week [322].

In a study among 912 males and females, a complete lack of association was observed between serum cholesterol levels and egg consumption [323]. In this study, it was observed that men in the highest third of the egg intake distribution had identical serum cholesterol levels to men in the lowest third (5.98mmol/L). Women eating fewer eggs demonstrated slightly higher serum cholesterol levels than those at the highest intake level (6.23 vs. 6.16mmol/L).

With respect to risk of coronary events, it was observed that individuals consuming more eggs were at a slightly higher risk but the difference was not statistically significant [323]. Moreover, the analysis did not account for any potential confounding factors.

A number of smaller studies examining egg consumption and plasma cholesterol and lipoprotein profiles identified contrasting findings. The intake of 3, 7 and 14 eggs/week was examined in 70 young healthy men who followed a high fat diet [324]. In all 3 study groups, egg intake in this range did not influence plasma lipids and lipoproteins; however the high saturated fat background diet may have concealed any possible effect of the dietary cholesterol.

In a 6 month study of 116 males who consumed 2 eggs/day in addition to their usual diet, no significant increase in mean serum cholesterol was found to be associated with increased egg consumption [325]. In contrast though, a small study investigated the effects on serum cholesterol of removal of eggs from the diet of free-living individuals [326]. The elimination of eggs from a habitual egg-rich diet resulted in a small but significant decrease in serum cholesterol levels in all subjects but no correlation could be demonstrated between changes in serum cholesterol levels and the number of eggs consumed per week [326].

Further, in a study that examined egg consumption and HDL-cholesterol in healthy individuals, the addition of 2 eggs/day for 6 weeks resulted in a 10% increase in serum HDL-cholesterol levels and an increase in total serum cholesterol of 4% [327]. The ratio of total cholesterol to HDL-cholesterol did not change significantly and LDL-cholesterol levels remained unchanged [327].

Since 2001 several additional studies have been published investigating the impact of eggs on serum cholesterol. One study showed that the consumption of two eggs daily for six weeks had no effect on serum total cholesterol or on endothelial function in healthy adults [328]. Another study reported that adding four eggs a day to a low-fat diet for four weeks increased HDL cholesterol levels in all subjects, and increased inflammatory markers and non-HDL cholesterol levels in lean insulin-sensitive subjects but not in lean or obese insulin-resistant subjects [329]. A third study showed the consumption of three eggs per day for one month among 42 postmenopausal women and men aged sixty years and over with healthy lipoprotein profiles increased both plasma LDL and HDL cholesterol levels, however the LDL:HDL and TC:HDL ratios did not change [330]. A 2006 study among 33 men and women aged 60 years and over found that eating one egg a day for five weeks did not cause an increase in blood cholesterol levels [192]. In 2006, the Japan Public Health Center-based study reported an inverse correlation between egg consumption and mean total cholesterol levels in people with normal and high baseline serum cholesterol levels (TC ≥ 5.8mmol/L). Those who ate eggs daily had lower total serum cholesterol levels than those who ate eggs less than once per week ($P < 0.0001$) [331].

A study that included 3 eggs per day as part of a carbohydrate restricted diet in overweight/obese men aged 40-70 years undergoing a 12 week weight loss intervention showed no change in LDL cholesterol levels, a reduction in plasma triglycerides, and a significant increase in HDL cholesterol and lutein levels compared to the control (egg substitute) group [332].

A 2012 study conducted in adults on cholesterol lowering medication, found feeding 3 eggs per day for 12 weeks resulted in increased HDL cholesterol and decreased LDL:HDL cholesterol ratio[333]. (note: there was no control group in this study)

Another study of 45 healthy male and female volunteers aged 18-55 years who were overweight or obese investigated the effect of energy restricted diets that included zero or two eggs per day for 12 weeks. Both groups lost weight over the 12 week period and plasma cholesterol also decreased over time in both groups as a result of a decrease in LDL cholesterol levels. These results occurred despite the fact that dietary cholesterol was increased by more than two fold in the egg-fed group to an average 582mg per day and decreased in the non-egg-fed group, who were advised to exclude eggs from their diet. This indicates that increasing dietary cholesterol by consuming 2 eggs a day produces no increase in total and LDL cholesterol when accompanied by energy restriction and moderate weight loss [334].

A review [335] aimed to dispel the public misconception that eggs and dietary cholesterol significantly increase blood cholesterol and subsequent changes to dietary recommendations. The article concluded that while dietary cholesterol can raise "bad" LDL cholesterol, the effect is small compared to that of saturated fat. Furthermore eggs increase good "HDL" cholesterol. However, despite this evidence and changes to dietary recommendations, the myth surrounding eggs and heart disease still exists among the public.

Apolipoproteins

A number of studies have assessed the effect of changes in dietary cholesterol intake from eggs on apolipoprotein levels with varying results. Some have shown no change in apolipoprotein B (the main apolipoprotein of LDL and VLDL levels which are considered important risk factors for cardiovascular disease) with increased dietary cholesterol from eggs [336-339] while others have shown an increase [340-344]. Most studies have found no change in apolipoprotein A-1 (the main protein of HDL) with increased intakes of dietary cholesterol from eggs [336-338,340,341,343,344].

High risk groups

People with hypercholesterolemia have been shown to demonstrate the same degree of response to increased dietary cholesterol from eggs as the remainder of the population [313,345,346] however studies in this area are limited. In a study of 33 patients with hyperlipidaemia (a combination of subjects with hypercholesterolemia, combined hyperlipidaemia and hypertriglyceridaemia), the addition of either two or seven eggs a week to a reduced fat, high fibre diet resulted in no change to total cholesterol, LDL, HDL or triglycerides after eight weeks [346]. While this study showed no negative effects of egg feeding in combined hyperlipidaemic subjects (those with high triglyceride and total cholesterol levels), the numbers were small (3 out of 33 subjects).

In contrast, another study showed patients with combined hyperlipidaemia exhibited greater increases in plasma cholesterol levels with increased egg intake compared with hypercholesterolaemic patients [345]. In this study, combined hyperlipidaemic subjects following the American Heart Association Step 1 diet for six weeks showed an increase in LDL cholesterol levels of 0.31mmol/L ($P < 0.001$) with the addition of two eggs a day and an increase in HDL cholesterol levels of 0.08mmol/L ($P=0.02$), compared to a non-significant increase in LDL cholesterol levels in hypercholesterolaemic subjects and a similar significant increase in HDL cholesterol levels (0.10mmol/L $P = 0.003$).

A recent study by Greene investigated the effects of dietary cholesterol from eggs on plasma lipids and LDL atherogenicity among postmenopausal women and men aged sixty years and over with healthy lipoprotein profiles [330]. Among these 42 subjects, consumption of three eggs per day for one month increased both plasma LDL and HDL cholesterol levels such that the LDL:HDL and TC:HDL ratios did not change. The peak LDL diameter also increased following egg consumption, which makes the LDL particles less atherogenic. The researchers therefore concluded that dietary cholesterol from eggs does not increase heart disease risk factors in a healthy elderly population, though further research is needed in this area.

People with type 2 diabetes are another high risk group for cardiovascular disease however no experimental studies on the effect of egg feeding on plasma cholesterol and lipoprotein levels have been conducted in this group. Further details on eggs and diabetes can be found in Section 8.

7.5 Hypo- and Hyper-Responders to Egg Consumption

Variations in cholesterol and/or lipoprotein profiles in response to egg consumption have been observed in groups shown to be hyper and hypo responders to dietary cholesterol.

Herron showed female hyper-responders to dietary cholesterol experienced an increase in LDL and HDL cholesterol levels with the addition of 640mg per day of dietary cholesterol from eggs (equivalent to 3.5 eggs a day). However there was no change in the LDL:HDL ratio [294]. Similar results were shown in men, where although there was an increase in the LDL:HDL ratio with the addition of 640mg dietary cholesterol from eggs, the ratio correlated with a low risk of coronary heart disease according to the clinical guidelines of the National Cholesterol Education Program adult treatment panel [347]. Another study found hyper-responders had a consistently lower LDL:HDL ratio compared to hypo-responders before, during and after an experimental period which involved the consumption of 3 eggs a day for 28 days in addition to their habitual diet [292]. The studies by Herron also showed an increase in dietary cholesterol from eggs enhances reverse cholesterol transport pathways in hyper-responders that mobilise the excess cholesterol to the liver, the major site of cholesterol elimination from the body [293,294].

The recent study by Greene showed that among 42 postmenopausal women and men aged sixty years and over with healthy lipoprotein profiles [186], consumption of three eggs per day for one month increased both plasma total, LDL and HDL cholesterol levels for hyper-responders ($P < 0.0001$) but not hypo-responders. Hyper-responders who consumed eggs had on average 20% higher total cholesterol (5.4mmol/L versus 4.5mmol/L), 26% higher LDL cholesterol (3.4mmol/L versus 2.7mmol/L), 10% higher HDL cholesterol (1.5mmol/L versus 1.4mmol/L) and 2% higher triglycerides (1.1mmol/L versus 1.08mmol/L) compared to the control group following egg consumption. Among hyper-responders, there was a significant increase in the larger, less atherogenic LDL particles during the egg treatment period.

The effects of egg feeding (2 eggs/day) were investigated in 161 hypercholesterolaemic (HC) or combined hyperlipidaemic (CHL) individuals following a controlled low fat, high fibre diet [345]. LDL-cholesterol levels were significantly increased (0.31mmol/L) in the CHL subjects and HDL-cholesterol increased significantly in both the HC and CHL groups (0.1mmol/L and 0.08mmol/L respectively). The authors concluded that the findings from this study suggest that CHL subjects may be sensitive to egg feeding and that these individuals may benefit from dietary cholesterol restriction.

Overall in hyper-responders, while increased egg consumption affects plasma lipids to a greater extent than in hypo-responders, further research is required to determine how this translates into cardiovascular disease risk.

7.6 Egg Consumption and Coronary Heart Disease

As eggs contain dietary cholesterol, which has a small effect on serum cholesterol levels, it has been assumed that a limit on egg consumption will reduce the risk of coronary heart disease (CHD) [319,347]. Furthermore, to avoid increases in blood cholesterol levels and reduce CHD risk, the general public has been advised by some health professionals to limit dietary cholesterol intake to less than 300mg/day and to restrict the consumption of eggs [319,347].

However, more recent scientific evidence indicates little association between restricting egg intake and a reduced risk of CHD and stroke in most people [348].

The lack of a consistent association between egg intake and risk of coronary heart disease may be explained by the small increase in plasma cholesterol levels following egg consumption that has been observed in experimental studies. Having an elevated plasma cholesterol level is, however, a major risk factor for CHD. McNamara has predicted that the increase in risk of myocardial infarction associated with a 100mg increase in dietary cholesterol from eggs, equivalent to half a medium egg or 3-4 eggs a week, has been estimated to range from 0.5% to 1.5% [316]. Furthermore, egg consumption largely results in the maintenance of the LDL:HDL ratio which is a key marker of CHD risk.

This theoretical increase in risk is considered minimal compared to other risk factors including the 72% increase in risk associated with increased body mass index, the 42% decrease in risk associated with replacement of 5% of energy from saturated fat with unsaturated fat and the 51% decrease in risk associated with 90 minutes of vigorous walking one day a week [316].

These findings were recognised by the American Heart Association (AHA) when revising their dietary guidelines for the general population in 2000. In their revised statement, the AHA acknowledged that *'dietary cholesterol can increase LDL cholesterol levels, although to a lesser extent than saturated fat'* and *'cholesterol-rich foods that are relatively low in saturated fatty acid content (notably egg yolks) have smaller effects on LDL cholesterol levels'* when compared with saturated fat. They suggest that daily targets for dietary cholesterol intake *'can readily be achieved even with periodic consumption of eggs'* [349]. The American Heart Association continues to recommend a daily cholesterol intake target of 300mg per day.

The National Heart Foundation of Australia recommends that consumption of up to 6 eggs per week in a diet low if saturated fat is not associated with adverse coronary heart disease outcomes but that consumption above this level may increase coronary heart disease in people with diabetes[350].

In January 2013, a meta-analysis of prospective cohort studies was published which investigated and quantified the dose-response association between egg consumption and risk of coronary heart disease and stroke[351]. In the analysis, 8 articles with 17 reports (9 CHD, 8 stroke) were included. The researchers found no evidence of an association between egg consumption and risk of coronary heart disease or stroke. When analyzing, only people with diabetes (based on 2 published studies), however, those with the highest egg consumption compared with the lowest had a 54% increased risk of coronary heart disease but a 25% decreased risk of stroke. Overall, up to one egg per day is not associated with CHD or stroke. Increased risk of CHD in diabetic population requires further research. The researchers did caution "These subgroup results should be interpreted with caution, because only a few studies focused on diabetic participants and particular stroke subtypes".

Overview of Epidemiological and Case-Control Studies
Fifteen epidemiological and case-control studies have assessed egg intake and subsequent development of CHD. Table 7 outlines these studies.

The most recent epidemiological studies that report on egg intake, the results of which have been released in 2008, are the Atherosclerosis Risk in Communities (ARIC) [352] and Physician's Health [353,354] studies.

The ARIC study is a population-based, observational cohort study which included 15,792 African-American and white men and women aged 45 – 64 years, and was conducted between 1987-1998 [352]. This study showed, when adjusting for different known confounders (energy intake plus demographics (age, sex, race, education level etc) plus lifestyle factors (smoking status, physical activity, alcohol intake) plus baseline history of disease (heart disease, stroke, diabetes, etc.), a 23% increased risk of heart failure for each extra serving of eggs consumed per day. Note however the authors did not adjust for other dietary variables such as total fat intake, saturated fat intake, and fibre intake. This means these factors may be considered confounders and may have influenced the results/conclusions. This study examined the association (not causality) between different foods with heart failure, and while an increase in egg intake by 1 serving per day (which effectively means 7 eggs/week) was shown to result in a 23% increased risk of heart failure, this study did not look at the association between consuming < 7 eggs per week and heart failure.

The Physician's Health study [353] reported data from 21,327 male participants aged 40 years and over at entry. The results showed that infrequent egg consumption did not increase the risk of CVD, however consumption of ≥7 eggs per week was associated with a 23% increased risk of death. Consumption of ≤6 eggs per week did not increase the risk of death. Frequent egg consumption was also associated with older age, higher body mass index, higher alcohol consumption, lower intake of breakfast cereals, lower levels of exercise and higher levels of smoking as well as other factors, and these may have influenced the results. The authors controlled for confounding factors such as exercise, alcohol consumption, body weight, smoking, diabetes, high blood pressure and high cholesterol, however they did not adjust for other dietary variables such as total fat intake, saturated fat intake, wholegrain intake, energy (kilojoule) intake or fruit/veg intake. This means these factors may be considered confounders and may have influenced the results/conclusions. Note this study does support other recent research that shows a greater risk in mortality from egg consumption of ≥7 eggs per week in people with diabetes (see section 8 for further details). In a separate study of the same cohort, it was found that infrequent egg consumption was not associated with increased risk of heart failure, however greater than or equal to one a day was associated with a 28% increased risk [354].

The Nurses Health Study (80,082 women) and the Health Professionals Follow Up Study (37,851 men) showed no association between levels of egg consumption of up to one a day and risk of CHD or stroke in both men and women [355]. However, in a sub-group analysis of both cohorts, higher egg consumption appeared to be associated with increased risk of CHD in people with diabetes. Despite this result, further analysis of the study showed that no figures were reported for the number of cases of type 1 or type 2 diabetes and the criteria used to determine diabetes were not reported. Relative risk of CHD in men and women with diabetes progressively increased with increasing egg consumption but absolute risk was not reported and there was no interaction between egg consumption and the presence of diabetes [355]. In a sub-group analysis of 1013 people with diabetes who were enrolled in the Greek arm of the European Prospective Investigation into Cancer and Nutrition (EPIC), a positive association was found between egg intake and diabetic mortality [356]. In a Finnish cohort of 5,133 men and women, there was no difference in egg consumption between individuals who developed fatal coronary heart disease and those who did not [357]. The Framingham Study also found no association between egg intake and subsequent development of CHD in a sub-sample of 912 people [323]. Similarly a prospective study of 90,735 subjects in the Japan Public Health Center-based study showed that although total cholesterol levels were significantly related to an increased risk of CHD, consumption of eggs almost daily was not associated with CHD risk in middle-aged Japanese men and women [331]. Another Japanese study (NIPPON DATA80) showed no effect of egg consumption on risk of fatal CHD events, stroke and cancer in men consuming up to two or more eggs a day, however in contrast, found an increased risk in women eating one egg a day or more [358].

The Oxford Vegetarian Study (11,140 vegetarians and meat eating study participants) showed a positive association between egg intakes of 6 or more a week and mortality from ischemic heart disease [359]. In contrast, the Adventist Health Study (34,192 vegetarian and non-vegetarian Seventh Day Adventists) found individuals consuming more than 2 eggs per week were at no different risk of developing CHD compared to those consuming less than one egg a week [360]. A recent study using data from the First National Health and Nutrition Examination Survey (NHANES1) in the US showed that among 9734 adults aged 25 to 74, no significant difference was observed between persons who consumed greater than 6 eggs per week compared to those who consumed none or less than 1 egg per week in regards to any stroke, ischemic stroke, or coronary artery disease over a 20-year follow-up. In a subgroup analysis among people with diabetes, consumption of greater than 6 eggs per week was associated with an increased risk of coronary artery disease [361].

The SUN Project[362] was a cohort study of 14,185 Spanish university graduates. During a median follow-up of 6.1 years, 91 new confirmed cases of CVD were observed. No association was found between egg consumption and the incidence of CVD for the highest (>4eggs per week) versus the lowest category (0 eggs per week) of egg consumption after adjusting for age, sex, total energy intake, adherence to the Mediterranean food pattern and other cardiovascular risk factors.

The ABC Health Study[363] was a long term population study of 1941 older adults aged 70-79 years, aimed to assess the association between dietary fats, cholesterol, and eggs and cardiovascular disease risk. During a 9 year follow up period, 203 cases of cardiovascular disease were reported, including heart attacks, coronary death and stroke. The study found no significant associations between dietary fats and cardiovascular disease risk. No association was found between egg intake, dietary cholesterol and cardiovascular disease risk in any group other than those with type 2 diabetes. Higher intakes of dietary cholesterol and egg intakes greater than 3 per week were associated with increased risk of cardiovascular disease.

Case-control studies

The INTERHEART study [364] is a global study which includes 12,461 patients who have had a heart attack and 14,637 controls free of heart disease. Subjects were recruited from 52 countries between 1999 and 2003. In this particular journal report, the number of subjects was confined to 5,761 cases and 10,646 controls. From the food intake data, three types of dietary patterns were identified based on the number of times certain foods were eaten: Oriental (characterised by higher intakes of tofu, soy and other sauces), Western (characterised by higher intakes of fried foods, salty snacks and meat) and Prudent (characterised by higher intakes of fruit and vegetables). The prudent dietary pattern was shown to be associated with a lower risk of developing a heart attack while the Western dietary pattern was shown to be associated with an increased risk. There was no association shown between the Oriental dietary pattern and heart attack risk. While higher intake of eggs was included as a characteristic factor in the Western dietary pattern, there was no association reported between eggs as an individual food and heart attack risk.

A case-control study of Italian women (287 cases, 649 controls) (found no association between egg consumption of greater than two serves a week and non-fatal myocardial infarction [365]. A Japanese case-control study (660 cases, 1,277 controls) that examined the relationship of selected foods to nonfatal acute myocardial infarction (AMI) found no association between egg intakes up to four or more a week and incidence of AMI [366].

Most of the above studies adjusted the data for non-dietary coronary risk factors, including hyperlipidaemia.

No data is available on the effect of eggs on recurrent coronary events in those with existing CHD.

Randomised Trials

A 2008 randomised trial that examined the effect of egg consumption on inflammatory markers found that consumption of three eggs daily made a significant contribution to the anti-inflammatory effects of a weight loss intervention using a kilojoule-controlled diet [367]. Subjects consuming the eggs had decreased plasma CRP levels, a marker of inflammation, and increased plasma adinopectin levels, a marker of insulin sensitivity. Taken together, these results indicate a lower risk of CVD in subjects consuming the eggs.

Table 7: Summary of epidemiological evidence regarding egg intake and CVD

Study	Design	Results
ARIC [352]	11 year follow up of 15,792 African-American and white men and women aged 45-64	23% increased risk of heart failure for each extra serving of eggs consumed per day (7 eggs/week)
Physician's Health [353,354]	20 year follow up of 21,327 male participants aged 40 years and over	Egg consumption did not increase CVD risk, but consumption of ≥7 eggs per week was associated with a 23% increased risk of all cause mortality and in a separate study of the same cohort, increased risk of heart failure by 28%. Consumption of ≤6 eggs per week did not increase the risk of death from all causes.
NHANES I [361]	20 year follow up of 9734 adults aged 25 to 74	No significant difference between consuming greater than 6 eggs per week compared to less than 1 egg per week in regards to any stroke, ischemic stroke, or coronary artery disease; consumption of greater than 6 eggs per week was associated with an increased risk of CHD in people with diabetes
Japan Public Health Center-based study [331]	21 year follow up of 90,735 male and female subjects aged 40-69	Total cholesterol levels were significantly related to an increased risk of CHD, however consumption of eggs almost daily was not associated with CHD risk in middle-aged Japanese men and women
Greek EPIC diabetic subgroup [356]	11 year follow up of 1013 Greek adults with diabetes	Positive association with daily egg intake and cardiovascular mortality in people with diabetes
NIPPON DATA80 [358]	14 year follow up of 5186 women and 4077 men aged 30 years and over	No effect of egg consumption on risk of fatal CHD events, stroke and cancer in men consuming two or more eggs a day; increased risk of all cause mortality in women eating one egg or more a day (but not CHD, stroke or cancer)
Nurses' Health [355]	14 year follow up of 80,082 women aged 39-54	No association between consumption of up to one a day and risk of CHD or stroke; possible increased CHD risk in people with diabetes

Health Professionals Follow-up [355]	14 year follow up of 37,851 men aged 40-75	No association between consumption of up to one a day and risk of CHD or stroke; possible increased CHD risk in people with diabetes
Oxford Vegetarian Study [359]	14 year follow up of 11,140 vegetarians and meat eating study participants	>6 eggs per week associated with increased mortality from ischemic heart disease
Adventist Health Study [360]	6 year follow up of 34,192 vegetarian and non-vegetarian Seventh Day Adventists found individuals	Consuming more than 2 eggs per week presents no difference in risk of developing CHD compared to consuming less than one egg a week
Finnish Study [357]	14 year follow up of 5,133 men and women aged 30-69	No difference in egg consumption between individuals who developed fatal coronary heart disease and those who did not
Framingham Study [323]	24 year follow up of a 912 person sub-sample	No association between egg intake and subsequent development of CHD
The SUN Project[362]	6 year follow up of 14,185 university students	No association was found between egg consumption and the incidence of CVD for the highest versus the lowest category of egg consumption.
Health ABC Study[363]	9 year follow up of 1941 70-79 year olds	No association was found between egg intake, dietary cholesterol and cardiovascular disease risk in any group other than those with type 2 diabetes. Higher intakes of dietary cholesterol and egg intakes greater than 3 per week were associated with increased risk of cardiovascular disease
INTERHEART [364]	Global study reporting on 5,761 patients who have had a heart attack and 10,646 controls free of heart disease, recruited over 4 years	Western dietary pattern (characterised by higher intakes of fried foods, salty snacks and meat) was shown to be associated with an increased risk of heart attack; no association between eggs and heart attack risk
Italian case-control study [365]	287 cases and 649 controls, all women, conducted over 5 years	No association between egg consumption of greater than two serves a week and non-fatal myocardial infarction
Japanese case-control study [366]	660 cases and 1,277 controls aged 40-79 years	No association between egg intakes up to four or more a week and incidence of acute myocardial infarction

A controversial 2012 study concluded that egg intake should be restricted in people at risk of vascular disease[368].In the study, 1231 patients, who were attending vascular clinics recorded data on egg consumption and their carotid total plaque area was measured. The total plaque area among people who consumed 2 or fewer eggs per week was approximately 7mm smaller than those consuming 3 or more eggs per week. Those consuming 3 eggs or more were older than those who consumed 2 eggs or fewer, but when this was accounted for a relationship between egg yolks and carotid plaque area was still significant.A number of issues with this study are noted, most importantly, that they did not correct for other dietary factors known to be important in heart disease risk such as saturated fat intake.

This study has raised quite a bit of controversy. In one letter to the editor of the journal Atherosclerosis, Finnish researchers provided data from their study population which showed no relationship between egg consumption and carotid plaque area or risk of heart disease[369]. The study population consisted of 1019 men with an average age of 51.5 years. On average, the men consumed 31g of egg per day (approx 3.9 eggs per week). After adjusting for a number of variables, the plaque area in the highest egg consumption group (approx 5.3 eggs per week) was lower but not significantly different from the lowest intake group (approx 1.8 eggs per week). Even extremes in egg consumption did not reveal any association. Some key differences between the Finnish study and the Spence study were highlighted including:

- In the Finnish study dietary intakes were assessed at the time of the carotid plaque measurement and prior to heart attacks while in the Spence research dietary intake was assessed earlier.
- Finnish people consume their eggs boiled, fried or in foods but seldom with foods such as bacon which may have unfavourable effects on health highlighting the issue of not controlling for other dietary factors.

It is also noteworthy that eggs provide nutrients that may be associated with protection from CHD or its risk factors. For example, a serve of eggs provides 16-32% of the suggested dietary target (SDT) value to reduce chronic disease risk for folate and 19-27% of the SDT for long chain omega-3 fatty acids for adults, nutrients that have been associated with a lower risk of CHD. Eggs also provide arginine, a precursor to nitric oxide, which in turn plays a central role in endothelial function [328]. The National Heart Foundation of Australia also recently recognised eggs as a nutritious food, with regular eggs becoming eligible for the healthy eating Tick of approval.

Example key messages:

- In healthy individuals, most population studies have shown no association between levels of egg intake up to six eggs per week and increased risk of heart disease.
- Research supports the inclusion of up to 6 eggs a week as part of a healthy diet for the management of diabetes.
- If there is a small increase in risk of heart disease through the addition of one egg a day, this increase in risk is non-significant when compared to the modification of other lifestyle related risk factors such as controlling body weight and reducing saturated fat intake.
- The current, best available evidence shows no association between egg consumption and risk of heart disease or stroke.

Interpretation of Evidence Relating to Egg Consumption

As demonstrated, the findings from epidemiological and clinical trials relating egg consumption to CHD risk are not consistent. However, an interpretation of the data suggests that egg intakes of up to 6 eggs per week may have little relationship to hypercholesterolaemia or increased CHD risk in the majority of the population, with the potential exceptions being diabetic and combined hyperlipidaemic individuals. Furthermore, up to 85% of the normal population will be hypo-responders to dietary cholesterol, so plasma cholesterol responses in the majority of individuals will already be lessened.

In conclusion, the scientific evidence shows little association between egg intake and CHD. In a healthy Western population, there is insufficient evidence to restrict egg intake as part of a healthy diet. Eggs should be considered in a similar way as other protein rich foods and selected as part of a varied diet that is low in saturated fat, high in dietary fibre and contains a variety of cardio-protective foods such as fish, wholegrains, fruits, vegetables, legumes and nuts. Substituting eggs for other animal protein foods in the diet may result in even smaller changes to LDL cholesterol than predictive equations as the net dietary cholesterol increase is smaller. In individuals at high risk, such as people with diabetes and those with hyperlipidaemia, there is little data to guide recommendations for egg consumption. However, prudent advice is that the inclusion of eggs in the context of a diet low in saturated fat and containing known cardio-protective components is not associated with increased risk.

Example key messages:

- Research supports the inclusion of up to six eggs per week as part of a healthy diet.
- Further research is required to fully assess the effects of egg consumption in those with coronary heart disease, hyperlipidemias (especially combined hyperlipidemias), or type 2 diabetes.
- Up to 85% of the population produce less cholesterol when dietary cholesterol intake increases. This mechanism serves to regulate blood cholesterol levels.

8. Scientific Review of Eggs and Diabetes

Currently one million Australians have been diagnosed diabetes, predominantly type 2[370]. If diabetes continues to rise at the current rates, up to 3 million Australians over the age of 25 years will have diabetes by the year 2025. For type 2, this is likely driven by rising obesity, the ageing population, dietary changes, and sedentary lifestyles[370]. Previously thought to only occur in adulthood, type 2 diabetes is now identified in younger age groups including children and adolescents. Diabetes is a strong risk factor for the development of cardiovascular disease, and if current rates continue to rise, it is possible the recent decline in heart disease may be reversed.

Plasma cholesterol is an important risk factor and aggressively treated in people with diabetes. Research conducted in the area of eggs, dietary cholesterol and diabetes management is limited in quantity and quality but is starting to accumulate. One epidemiological study has examined the risk of developing type 2 diabetes based on egg consumption. Four epidemiological studies have examined the association between egg consumption and coronary heart disease (CHD) risk or mortality in people with type 2 diabetes. Three clinical investigations have been carried out, one in people with type 1 diabetes and two in people with insulin resistance, and these studies have found varying results. One suggested a positive relationship between egg consumption and plasma cholesterol levels in subjects with type 1 diabetes, one found the effect of dietary cholesterol from eggs was less in insulin resistant subjects compared to insulin sensitive subjects, while the other found no difference between insulin sensitive and insulin resistant subjects [371-373]. Further research is therefore required before any clear recommendations can be made in relation to egg consumption in people with diabetes.

8.1 Epidemiological Evidence

A 2008 study [374] presented results of 20,703 men aged 40 years and over and 36,295 women aged 45 years and over from the Physicians' Health Study I (PHS I) from 1982-2007 and the Women's Health Study (WHS) from 1992-2007. Those who ate eggs most frequently had a higher body mass index (higher weight), were more likely to be smokers and have high blood pressure than the lowest egg consumers. In men, frequent egg consumption was also associated with older age and higher alcohol consumption, while in women, it was associated with higher energy, saturated fat, trans fat and dietary cholesterol intake. Interestingly, the highest egg consumers were less likely to have pre-existing high cholesterol levels.

Men who ate one or less than one egg per week had a 9% higher risk of type 2 diabetes than those who consumed no eggs; the risk was 18% higher for 2-4 eggs per week, 46% higher for 5-6 eggs per week and 58% higher for 7 or more eggs per week. The increase in risk was only statistically significant for the two highest consumption groups i.e. for those eating 5 or more eggs per week, but there was an overall statistical trend showing an increased risk of getting type 2 diabetes with increased egg consumption. In women, the risk was 6% higher for eating less than one per week (compared to no eggs), 3% *lower* for those eating 1 egg per week, 19% higher for 2-4 eggs a week, 18% higher for 5-6 eggs a week and 77% higher for 7+ eggs. The increase in risk was only significant for the groups of 2-4 eggs per week and 7 or more eggs per week, but again there was a trend showing an increased type 2 diabetes risk with increased egg consumption

When grouped by blood cholesterol level, the observed increase in risk of type 2 diabetes in men with normal blood cholesterol decreased from 46% to 34% for 5-6 eggs per week and from 58% to 47% for 7 or more eggs per week. However, the effect of egg consumption was greater in men with high/treated blood cholesterol, with the increase in risk for those eating 5-6 eggs per week increasing from 46% to 78% and that for 7 or more eggs per week increasing from 58% to 96%. However, even with these groupings, having 4 or less eggs per week did not confer a significant increase in risk of developing type 2 diabetes.

In the case of women, for those with normal blood cholesterol levels, having 7 or more eggs per week resulted in a significantly increased risk of type 2 diabetes (84% increased risk) while for women with high/treated cholesterol only those having 5-6 eggs per week were shown to have a significantly increased risk but not 7 or more eggs per week. Higher dietary cholesterol intake in women (independent of egg intake) was associated with a higher risk of type 2 diabetes, while interestingly a higher intake of saturated fat was not associated with type 2 diabetes.

While the analyses controlled for a number of factors known to be associated with type 2 diabetes, the authors did not adjust for baseline dietary cholesterol intake, or intake of wholegrains or fibre which are known to reduce the risk of type 2 diabetes and affect blood glucose responses. Among men in particular, data on other dietary variables such as total fat, saturated fat and energy (kilojoule) intake as well as family history of diabetes were not available, therefore all potential interactions were not fully considered, and this may have had an impact on the results. The results of this study should be interpreted with caution in the general population, however it may be concluded that the consumption of ≥ 4-7 eggs/week may be associated with an increased risk of type 2 diabetes in older male physicians and female health professionals.

A subgroup analysis from the Health Professionals Follow-up Study and the Nurses' Health Study where dietary data was collected using a food frequency questionnaire, showed the risk of CHD and stroke may be elevated with increasing egg intake in people with diabetes [355]. However, no figures were reported for the number of cases of type 1 or type 2 diabetes and the criteria used to determine diabetes were not reported. The multi-variate relative risk (RR) models used in the analysis adjusted for total energy, smoking, alcohol, history of hypertension, parental history of myocardial infarction (MI), body mass index (BMI), current multivitamin use and vitamin E supplement use. Relative risk of CHD in men and women with diabetes progressively increased with increasing egg consumption but absolute risk was not reported and there was no interaction between egg consumption and the presence of diabetes. In men with diabetes, the relative risks of CHD were less than 1 egg per week (1.0), 1 per week (1.0), 2 to 4 per week (1.16), 5 to 6 per week (1.16), and 1 or more eggs per day (2.02); (95% CI, 1.05-3.87; p=0.04 for trend and p=0.18 for interaction between egg consumption and diabetes status). The corresponding relative risks for women with diabetes were 1.0, 0.91, 1.05, 1.87, and 1.49 (95% CI, 0.88-2.52; p=0.008 for trend and p=0.07 for interaction). Statistical interpretation of the results from this study indicates that the more eggs a person with diabetes ate, the higher the risk of CHD, however this was not due to the presence of diabetes. As this association was not found in people without diabetes, it may be a chance finding, particularly as the baseline dietary cholesterol intake had no effect on risk of CHD in people with diabetes, that is, whether dietary cholesterol intake was high or low the risk of CHD was the same.

Subsequent analysis of data from the Nurse's Health Study showed that CVD risk was increased with higher intakes of both cholesterol and saturated fat in the 5,674 women within the cohort who had type 2 diabetes diagnosed between 1976 and 1996 [306]. In this study, the RR of CVD for an increase of 200mg cholesterol/1000kcal (equivalent to one egg per 1000kcal) was 1.37 (95% CI: 1.12-1.68; p=0.003).

A subgroup analysis from the First National Health and Nutrition Examination Survey (NHANES-1) where dietary data was collected using a food frequency questionnaire, showed the risk of coronary artery disease (CAD) was elevated in people with diabetes consuming greater than six eggs per week [361]. However, this result was not found among people without diabetes. In this study the relative risk of CAD in people with diabetes consuming greater than six eggs per week was 2.0 (95% CI: 1.0-3.8; p=0.16783). No association was found between egg consumption and risk of stroke or ischaemic stroke. The authors noted that the association between egg consumption and CAD in people with type 2 diabetes warrants further investigation.

A sub-group analysis of 1013 people with diabetes who were enrolled in the Greek arm of the European Prospective Investigation into Cancer and Nutrition was published in 2006 [356]. In this study, participants were only included if their diabetes was managed through oral medication or insulin. All individuals were also taking drugs for hypertension and/or hypercholesterolemia. Dietary data was collected during the year preceding enrolment and assessed through a validated, interviewer-administered food frequency questionnaire that included approximately 150 items. For the analysis, 16 different categories for foods, beverages and some nutrients were developed, including a category for eggs. The egg group included both whole eggs and all egg dishes, such as desserts and mayonnaise. Participants were followed up for 4.5 years and 80 deaths occurred during this timeframe, 46 from CVD, 19 from cancer and 15 from other causes. Of the food groups analysed, only the egg group was significantly, positively associated with diabetic mortality (hazard ratio 1.31 for an increase of 10g daily). Saturated fat also showed a positive, significant association with diabetic mortality (hazard ratio 1.82 for an increase of 10g daily) while physical activity was protective.

In this study, no information on quintiles of intake is presented, therefore making it difficult to assess whether a dose response effect exists. In addition, the study did not state how well the subject's diabetes was controlled and when measuring the effects of eggs, the authors did not adjust for saturated fat intake. While the authors conclude that the association between egg intake and mortality may be explained by people with diabetes having impaired regulation of blood lipids, there may also have been confounding factors that were not accounted for that may explain the results of this study. In particular, the increase in risk seen with increased consumption from the egg food group may be attributable to other factors such as how the eggs were cooked and the foods with which they were served.

A study of 3898 men and women looked at the association between egg intake and incidence of diabetes in older adults[375].Results found that during a follow-up of 11.3 years, there was no association between egg consumption and increased risk of type 2 diabetes in either men or women. Furthermore, in a secondary analysis, dietary cholesterol was not associated with incident diabetes. In addition, egg consumption was not associated with differences in fasting glucose, fasting insulin, or measures of insulin resistance.

Another study was an examination of the data from the US Physician's Health Study I which included 21,327 male participants [353]. Abbreviated food frequency questionnaires were used to determine egg intake, and the results showed that while egg consumption was not associated with incident MI or stroke, consumption of ≥7 eggs per week was associated with a 23% increased risk of death in non-diabetic participants. Consumption of ≤6 eggs per week did not increase the risk. Among physicians with diabetes, a significant trend existed. As the number of eggs consumed per week increased, the risk of all cause mortality also increased (p for trend < 0.001). However the highest risk appeared in those consuming 5-6 eggs per week (127% greater risk than consumption of <1 egg per week), while participants consuming >7 eggs per week had a lower all-cause mortality than the 5-6 eggs per week group (101% greater risk).

The association of consumption of 4 or less eggs per week with all-cause mortality was not statistically significant. Additionally, while the authors concluded there was ‘suggestive evidence for a greater risk of MI and stroke’ from increasing egg consumption among those with diabetes, the interactions were not statistically significant (P for trend = 0.93 for MI and 0.52 for stroke). In this study, frequent egg consumption was associated with older age, higher body mass index, higher alcohol consumption, lower intake of breakfast cereals, lower levels of exercise and higher levels of smoking as well higher prevalence of diabetes and hypertension, and lower prevalence of hypercholesterolemia. However while the analyses controlled for exercise, alcohol consumption, body weight, smoking, diabetes, high blood pressure and high cholesterol levels, it did not adjust for dietary variables such as total fat, saturated fat, energy (kilojoule) or fibre intake, or wholegrain or fruit intake. Therefore due to these numerous potential confounding factors, it cannot be concluded that egg consumption increases the risk of mortality as indicated in this study.

A study of 234 subjects, aged 35-86 years, found that the consumption of more than 3 eggs per week was associated with a twofold increased risk of type 2 diabetes. Consumption of 5 or more was linked with a threefold increase in risk[376]. Case subjects (those with diabetes) had significantly lower education level and higher BMI than control subjects (those without diabetes). These were however controlled for.

In January 2013, a meta-analysis of prospective cohort studies was published which investigated and quantified the dose-response association between egg consumption and risk of coronary heart disease and stroke[351]. When analyzing, only people with diabetes (based on 2 published studies), those with the highest egg consumption compared with the lowest had a 54% increased risk of coronary heart disease but a 25% decreased risk of stroke. The researchers suggested the ncreased risk of CHD in diabetic population requires further research with the caution: “These subgroup results should be interpreted with caution, because only a few studies focused on diabetic participants and particular stroke subtypes”.

These are the only epidemiological studies published that have reported effects of eggs or dietary cholesterol on the risk of developing type 2 diabetes, CHD, CVD and total mortality in people with diabetes. Additional research is essential to further establish the role of eggs and/or dietary cholesterol in relation to the risk of CHD in people with type 2 diabetes.

Associations have also been found between obesity, metabolic syndrome [377] and Type 2 diabetes [378] and low vitamin D status. Although the exact mechanism is unclear, vitamin D, of which eggs are a source, plays a role in pancreatic cell function. Low levels of vitamin D may therefore impair insulin action and alter the body’s response to glucose [378]. Another theory is that the large fat stores of obese people take up extra vitamin D, lowering the concentration in the blood. Despite these possibilities vitamin D supplementation has not been shown to influence blood sugar or insulin levels in those with impaired glucose intolerance [379].

8.2 Experimental Evidence

A small, double-blinded crossover designed clinical trial investigated the effects of dietary cholesterol from eggs on the blood lipid profile of ten males with type 1 diabetes and compared the results to 11 matched controls [371]. A liquid supplement containing 800mg/day dietary cholesterol from egg yolks (the amount found in four large eggs), or a placebo, was taken for 3 weeks. The background diet was controlled for macronutrient intake including saturated fat intake. The 800mg daily dietary cholesterol supplement increased total plasma cholesterol levels by 6.4% in those with type 1 diabetes and 9.4% in controls ($p<0.05$) while LDL levels increased 12% ($p<0.01$) and 7% ($p<0.05$) respectively. No changes in VLDL and triglycerides were observed and HDL levels remained stable in IDDM subjects but increased in controls.

A larger prospective clinical trial conducted with insulin sensitive and insulin resistant postmenopausal women randomized study participants to one of three dietary interventions for 4 weeks following a 4 week washout period. The people were tested for insulin sensitivity at baseline using the Insulin Suppression Test. Baseline cholesterol levels varied between 2.99mmol/L and 6.76mmol/L. Total and LDL cholesterol concentrations changed very little in either insulin sensitive or insulin resistant people when cholesterol intake from eggs was either 113mg (washout period), 319mg, 523mg or 941mg per day for a period of 4 weeks [372]. All four diets conformed to the US National Cholesterol Education Program (NCEP) Step 1 diet containing (as a percent of total kilojoules) 20% protein, 50% carbohydrate, 30% fat, with 9% saturated fat, 9% polyunsaturated fat, and 12% monounsaturated fat.

The largest clinical trial investigating the effect of egg intake on insulin resistant people conducted to date was a double-blind randomised crossover with three one-month interventions [373]. The primary aim of the study was to determine whether insulin resistance, with or without obesity, influences LDL response to dietary cholesterol and saturated fat. After completing a Frequently Sampled Intravenous Glucose Tolerance Test (FSIGT) as a test of insulin sensitivity, the post hoc analysis divided participants into insulin resistant (IR), insulin sensitive (IS) and obese insulin resistant (OIR) cohorts. A significant increase in total cholesterol levels was observed in all 3 groups however was greatest in the IS group. LDL cholesterol increased significantly in the IR and IS groups, however was less in the IR group. LDL cholesterol did not change in the OIR group. Analysis of co-variance showed no significant effect of baseline differences in LDL cholesterol or dietary intake of cholesterol, saturated or polyunsaturated fat in the background diet. HDL cholesterol significantly increased for all people consuming two or more eggs per day, except for the OIR people when this only occurred at a consumption level of four eggs per day. Obese insulin resistant people represent the majority of people at risk of type 2 diabetes. This study therefore suggests that egg intake has very little impact on the plasma lipid levels of this sub-group and that the change in lipid levels is even less than that seen in healthy, insulin sensitive people.

Conclusion

Epidemiological evidence regarding the role of eggs in the risk of developing diabetes is sparse and findings inconclusive. The only studies available in this area are those that have assessed the role of eggs or dietary cholesterol on the risk of coronary heart disease, CVD or total mortality in people with type 2 diabetes. The three clinical trials are difficult to interpret due to variability in the results, the different methodologies used and the various subject groups studied. In addition, the studies identified to date have only measured the effect of eggs on lipid levels in subjects with insulin resistance in which the presence of this condition had no effect, and type 1 diabetes, in which LDL particle mass was significantly increased. Furthermore, no studies have measured the effect of egg consumption on diabetes control using indicators such as blood glucose levels or HbA1C levels.

Further research is required to fully assess the effect of egg consumption in people with diabetes. It is well established that lipid control is an important part of management for people with diabetes, which includes diet, physical activity, and, pharmacotherapy. However, prudent advice is that the inclusion of eggs in the context of a diet low in saturated fat, containing known cardio-protective foods and meeting the dietary guidelines for diabetes management is not associated with increased risk.

Example key messages:

- Further research is required to fully assess the effect of egg consumption in people with diabetes.
- The inclusion of eggs in the context of a diet low in saturated fat, containing known cardio-protective foods and meeting the dietary guidelines for diabetes management is not associated with increased risk.
- Research supports the inclusion of around 6 eggs a week as part of a healthy diet for the management of diabetes.

9. The Role of Eggs Through The Lifecycle

This section outlines key health and nutrition issues of relevance to people at different stages of the lifecycle, and the role that eggs may play at each stage. Appendices 12.1-12.4 highlight Recommended Dietary Intakes of nutrients for the different stages of life and the amount contributed by a standard serve of eggs.

9.1 Pregnancy and Lactation

Pregnancy and lactation increase a woman's nutritional requirements for key nutrients such as energy, protein, omega-3 fatty acids and most vitamins and minerals including folate, iron and zinc. Adequate nutrition during pregnancy is essential to optimise both maternal health and that of the developing child [380]. Australian infant feeding guidelines recommend women breastfeed for at least six months to ensure optimal nutritional status of the infant [11]. Dietary intake of certain nutrients can be reflected in levels present in breast milk, emphasizing the importance of good nutrition during this time of life.

Energy

Throughout pregnancy, kilojoule intake must be sufficient to allow optimal weight gain of the developing foetus. Energy requirements for pregnancy increase by 1400 kilojoules/day in the second trimester and 1900 kilojoules in the third trimester [2]. Thus, the total energy needs during pregnancy range between 2,500 to 2,700 kcal (10500 to 11340kJ) a day for most women. However, the mother's pre-pregnant body mass index, maternal age, rate of weight gain, and physiological appetite must be considered in tailoring this recommendation to the individual [380].

There is recent evidence to suggest that many women in developed countries are not meeting recommended intakes for energy in pregnancy[381], therefore potentially jeopardizing their ability to meet their increased nutritional requirements at this time [5]. In Australia/NZ average energy intakes in pregnancy were found to average 9261 +/- 1101kJ/day[381]. Many women also experience morning sickness and heartburn during their pregnancies, which can lead to a reduction in the variety of foods eaten and/or frequent vomiting. Not surprisingly energy intakes in the 3rd trimester are significantly higher than the first trimester[381]. As a result, nutrient availability and absorption may be reduced. The American Dietetic Association [380] recommends eating small frequent meals as one strategy to overcome these symptoms. Consumption of nutrient dense foods that are easily tolerated is also important at this time and eggs may play a useful role in this regard.

Lactation increases a woman's energy requirements by 2000-2100 kilojoules a day [2]. A serve of eggs is a nutrient dense source of energy that provides more than a quarter of the increased energy requirement for lactation.

Women who are overweight prior to pregnancy are encouraged to gain less weight than women of a healthy body weight [382]. While there are no recommendations for optimal weight gain for women during pregnancy in Australia, Table 8 outlines the US recommendations for women with various body weights at the beginning of pregnancy. Total food quantity may be limited in order to reduce the rate of weight gain in overweight and obese women [382].

Table 8: Guidelines for prenatal weight gain[383]

Body Mass Index (BMI)	Recommended wgt gain	Wgt gain per week after 12 weeks
<18.5	12.5 to 18 kg	0.5 kg
18.5 to 24.9	11.5 to 16 kg	0.4 kg
25.0 to 29.9	7 to 11.5 kg	0.3 kg
≥30	5-9 kg	0.2 kg
Other: **Twin pregnancy** **Triplet pregnancy**	Insufficient information	

As a result, meeting the increased nutrient requirements for pregnancy may be more challenging for overweight women. Eggs are a nutrient dense food, enabling women to eat lesser amounts without compromising nutritional status. Two 60gram eggs provide 581kJ, 31-42% of the average additional kilojoule requirement during pregnancy and 28-29% of the additional kilojoule requirement during lactation, while providing up to 200% or more of the additional requirements for a selection of vitamins and minerals. Table 9 shows the extra nutrients required during pregnancy, and the amount provided by one serve of eggs.

Table 9: Additional Nutrient Requirements During Pregnancy [2]

Nutrient	Additional requirements during pregnancy	% additional RDI provided by 2x 60gram eggs
Protein	14g	91%
Iron	9mg	18%
Zinc	3mg	17%
Folate	200μg	49%
Iodine	70μg	61%
Vitamin B12	0.2μg	>200%
Vitamin A	100μg	>200%

Protein

Pregnant and lactating women require additional dietary protein to support the growth and development of the infant. Recommendations for protein are increased by 14grams a day during pregnancy, and an extra 21grams a day is recommended during lactation [2]. A serve of eggs provides 12.7grams of protein, accounting for almost 100% of the additional protein requirements during the 2nd and 3rd trimesters of pregnancy. The protein in eggs provides all the essential amino acids and is of a high bioavailability[214], which makes them a particularly useful source of protein during pregnancy and lactation. The latest National Nutrition Survey reports the average daily intake of protein of women of child-bearing age adequately meets their increased protein requirements [384]. Average protein intakes in pregnant Australian and New Zealand women were recently found to be 86.9 +/- 11.8g per day (well above the recommended 60g per day)[381], however vegetarians who are pregnant or lactating can have reduced protein intakes and eggs may play a particularly useful role in this instance.

Iron

Many women have difficulty maintaining iron stores during pregnancy [380]. Results from a 2013 systematic review and meta-analysis showed intakes of iron in Australian and New Zealand pregnant women is well below recommendations in many women[385].The demand for iron significantly increases during the second trimester and peaks in the third when foetal demands are greatest [5]. The recommended dietary intake (RDI) of iron for pregnant women is 27mg/day [2], one third higher than the RDI for non-pregnant women of 18mg.

To assist in meeting the significantly increased iron requirements, maternal absorption rate of iron increases considerably during pregnancy from 7% at 12 weeks gestation to 66% at 36 weeks [5]. The Iron Status Advisory Panel recommends iron supplements if serum ferritin levels are below 16µg/L after 28 weeks of pregnancy to ensure the maintenance of maternal iron status and prevent against foetal iron deficiency [386]. Lactating women have a lower RDI for iron than non-pregnant women with the recommendation being 9-10mg/day [2]. Two eggs provide 1.7mg of iron, making them a useful contribution to baseline intake. However, the iron in eggs has a lower bioavailability compared to red meat (5% compared to 15%) [108].

Zinc

Zinc plays a vital role in the development of genetic material [5]. Pregnancy confers an increased requirement for zinc, which is reflected in the RDI (11mg/day compared with 8mg/day for non-pregnant women). Zinc requirements during lactation are increased further to 12mg/day [2]. Obtaining sufficient amounts of zinc during pregnancy is important, as maternal zinc deficiency is associated with growth retardation, preterm delivery, and abnormality in the foetus, and pregnancy-induced hypertension and birth complications in the mother [5]. Women taking iron supplements may have difficulty achieving recommended zinc intake as iron to zinc ratios exceeding three to one can impair zinc absorption [5]. Vegetarian diets may also make achieving zinc recommendations particularly difficult as they tend to be high in fibre which interferes with zinc absorption, and low in animal products which provide the best, most easily absorbed sources of zinc. Two eggs provide 0.5mg zinc, 17% of the additional zinc required in pregnancy.

Folate

Folate is required for foetal cell division and growth and is vital in preventing foetal neural tube defects such as spina bifida. Folate needs are therefore highest prior to conception and during the first few weeks of pregnancy [2], and a 400-500µg folate supplement at these times is recommended [387]. The RDI for folate during pregnancy is 600µg/day and 500µg/day in lactating women [2]. One serve of eggs* provides 16% of the RDI for pregnant women and 19% of the RDI during lactation. Results from a 2013 systematic review and meta-analysis showed intakes of folate in Australian and New Zealand pregnant women is well below recommendations in many women[385]

Research conducted in Canada has assessed the bioavailability of folate from eggs. A presentation at the Egg Nutrition for Health Promotion conference in 2004 found folate from eggs has a higher bioavailability compared to folate fortified foods and supplements [94]. This finding may have particular benefits during pregnancy and lactation where requirements for folate are significantly higher than usual.

Vitamin B12

Vitamin B12 is required for growth and development, manufacturing DNA, functioning of the nervous system and producing red blood cells. Vitamin B12 requirements are increased during pregnancy and lactation to ensure adequate maternal levels and breast milk content (1µg per litre) [5]. The RDI during pregnancy is 2.6µg/day and 2.8µg/day in lactating women [2]. Eggs provide a valuable source of vitamin B12 during pregnancy, particularly for ovo-vegetarian women, with one serve providing over 30% of the RDI for pregnancy (0.8µg/serve). Research shows that both lacto and lacto-ovo vegetarians during pregnancy have low vitamin B12 levels [388]. Studies have shown that vitamin B12 deficiency symptoms are present in 92% of vegan women and 72% of lacto and lacto-ovo vegetarians [105]. Considering this high rate of vitamin B12 deficiency, it is essential to encourage vegans to take supplemental vitamin B12 and for lacto and lacto-ovo vegetarians to be consuming sufficient quantities of animal derived foods in their diet.

Vitamin A

Vitamin A requirements are increased by 100µg/day retinol equivalents (RE) during pregnancy, for women over the age of 19 years, and all lactating women are advised to increase their vitamin A intakes by 400µg RE to reach an average daily intake of 1100µg RE/day [2]. Vitamin A is a fat-soluble vitamin and animal products, such as eggs, contain a preformed type of vitamin A that is highly bioavailable and also best absorbed from food sources containing fat [5]. Eggs contain this preformed vitamin A within a matrix that naturally contains fat, and it is expected that the vitamin A from eggs is highly bioavailable. Two eggs provide 239µg RE (30% RDI during pregnancy and 22% RDI for lactation). The safe upper limit for pregnancy and lactating women is 3000µg for those aged over 19 years [2]. It is recommended that women be encouraged to obtain vitamin A from the diet rather than supplementation [389,390].

Vitamin D

Vitamin D is important for bone health, and poor intakes during pregnancy can cause adverse outcomes to the newborn [120]. . Results from a 2013 systematic review and meta-analysis showed intakes of vitamin D in Australian and New Zealand pregnant women is well below recommendations in many women[385].

A review[43] of the importance of vitamin D in pregnancy and lactation has outlined research findings (mainly from association studies) that show the following potential benefits of vitamin D: maintenance of immune system of both mother and fetus, protection against impaired fetal growth and other adverse outcomes such as preeclampsia, bacterial vaginosis; decreased likelihood of ceaseran delivery. A 2012 systematic review also found low vitamin D levels were associated with adverse fertility parameters, preeclampsia, gestational diabetes or higher blood glucose, bacterial vaginosis, primary cesarean section, none or a few days' shorter gestation and post partum depression[44]. Similarly, a systematic review and meta-analysis concluded that low maternal vitamin D levels in pregnancy may be associated with an increased risk of preeclampsia, gestational diabetes mellitus, preterm birth and small-for-gestational age[45]. In addition, a 2012 cohort study of 977 women has found lower vitamin D levels in pregnancy is associated with lower fat mass at birth but higher fat mass at ages 4 and 6 [46] and a study of 1820 Spanish mothers has found higher levels of vitamin D in pregnancy were associated with improved mental and psychomotor development in 14 month old infants[47]. A 2010 study also suggests that vitamin D may be important in pregnancy in order to prevent respiratory infections during infancy and wheezing during early childhood[391]

Vitamin D is obtained from exposure of the skin to sunlight, and a few dietary sources including fortified margarines and milk, eggs, fish and fish oils [34]. Supplementation may therefore be necessary during pregnancy for women with low vitamin D intake and poor sun exposure [120,392]. The requirements during pregnancy are 5µg/day and eggs contribute 16% of the dietary requirements of vitamin D during pregnancy and lactation [2]. A study in Irish pregnant women revealed eggs as one of the main dietary contributors of vitamin D during pregnancy[83]. A 2012 study in pregnant women in Denmark found vitamin D deficiency to be approximately 31%[393]. Vitamin D defciency was directly associated with winter season, increasing pre-pregnancy BMI, and smoking, but was less frequent in women who had not given birth previously and tanned Caucasians[393].

Omega 3s

There is evidence to suggest that the intake of omega-3 fats during pregnancy may play an important and modifiable role in gestational duration and parturition [241]. Another study indicated that high-DHA eggs were well accepted amongst pregnant women and that egg consumption increased DHA intake and improved blood phospholipid DHA levels [238].

Studies have also investigated omega-3 enriched eggs and their impact on maternal and infant health. Research has shown that including four omega-3 enriched eggs per week in weaning diets may lead to 30-40% greater concentrations of omega 3 in the red blood cells of infants compared with infants not consuming omega 3 enriched eggs [113]. In addition, a 2000 study showed that lactating mothers who consumed two omega 3 enriched eggs per day for six weeks after birth increased the omega 3 content of their plasma and breast milk, resulting in higher infant plasma omega 3, and without adversely affecting cholesterol levels [394]. This may offer significant benefits for development of visual acuity and neurological developmental outcomes. A 2004 study showed an increase in red blood cell DHA levels in infants fed baby food enriched with egg yolk and DHA [273]. This in turn resulted in a significant increase in visual acuity in infants from six to twelve months compared to control infants not receiving the DHA enriched egg yolk [273]. More information on the benefits of omega 3 can be found in Section 6 of this report.

The major source of omega-3 in the diet is fish, which can often be limited during pregnancy due to concerns about mercury content. To ensure an adequate intake of all types of omega-3 fatty acids, including DHA, EPA and alpha-linolenic acid, pregnant women should be encouraged to consume a variety of omega-3 rich foods. Such foods include fish, leafy green vegetables, some nuts and vegetables and omega-3 enriched eggs. The recommended Adequate Intake (AI) for long chain omega-3 during pregnancy is 115mg per day. A serve of regular eggs contains 114mg of long chain omega-3, which represents 99% of the daily AI.

Iodine

Iodine is a mineral essential for normal thyroid function and production of thyroid hormones. Iodine deficiency during pregnancy can cause miscarriage, stillbirth and mental impairment [120]. Iodine is found in foods such as kelp and seafood, but the main dietary source is iodised salt. A 2005 study found 40-50% of Australian pregnant women have mild iodine deficiency [126]. A study of pregnant women in Western Sydney also found high levels of mild to moderate iodine deficiency (prior to mandatory fortification), however, there appeared to be no evidence of a significant adverse effect on thyroid function[395]. Suggested reasons include variations in iodine levels of fortified foods, and consuming rock or sea salt varieties which are not iodised [396]. The RDI for iodine increases by 70 and 120µg/day during pregnancy and lactation respectively. A serve of eggs contains 43µg of iodine, 20% of the RDI during pregnancy. Pregnant women who already use salt are advised to use iodized salt [127]. Others may benefit from an iodine supplement to improve their iodine status throughout their pregnancy [128].

Choline

Requirements for choline are increased during pregnancy and lactation as choline is transported through the placenta and mammary gland to the developing infant. The fetus and nursing infant place heavy demands on the mother for providing choline such that choline availability is compromised during pregnancy and lactation and cannot be synthesized in sufficient quantities within the body to meet metabolic demands, hence must be obtained from the diet [131]. Choline is required for the normal development of brain tissue in infants and plays an important role in maternal nerve and brain functioning. The adequate intake (AI) for choline is 440mg/day when pregnant and 550mg/day when lactating [2] . American research has shown that adding an egg to the diet each day could increase the number of pregnant women meeting the AI from 10% to more than 50% [397].Eggs, soy and other animal based foods are the main food sources of choline [4].

Choline is part of the phospholipid lecithin and has a high bioavailability in eggs. Eggs also contain vitamin B12, folate and methionine, which are used to synthesize choline in the body. Research from animals has indicated that, for humans, including two eggs a day may be beneficial for mothers in order to achieve adequate choline intake [397].

A 2009 study in more than 180,000 pregnant women already supplemented with folate found that higher levels of total blood choline were associated with a 2.5-fold reduction in risk for neural tube birth defects (NTDs). NTDs are birth defects of the brain and spinal cord, and the two most common NTDs are spina bifida and anencephaly.[135] Furthermore, recent research has suggested that choline intake during pregnancy may have a significant effect on the stress hormone, cortisol in the offspring[398]. The findings suggest that high intakes (930mg per day versus 480mg per day) of choline in pregnancy improve the stress response in children by lowering cortisol levels[398]. Cortisol levels play a role in a number of stress-related diseases such as mental, metabolic and heart disease[399].

Other Important Nutrients during Pregnancy

Calcium is a mineral essential for building bone in the developing foetus. Food sources of this nutrient include dairy products, calcium-enriched soy products and fish with bones [5]. Although the component of eggs normally consumed (the yolk and the white) is deficient in calcium, the egg shell is a rich source in the form of calcium carbonate. By grinding the egg shell to a powdered form, it can be consumed by humans to provide a significant source of calcium. However this is not a common practice in Australia as calcium can be found from a variety of other foods [400]. The RDI for calcium during pregnancy and lactation does not increase, however the mean daily calcium intake of Australian women of child bearing age is 750-762mg [8], well below the target of 1000mg/day [2]. Particular attention to achieving calcium intakes during pregnancy is therefore required.

Pregnancy is a time of increased nutritional requirements with only a moderate increase in total kilojoule requirements. It is therefore essential to consume a nutrient dense diet, which includes a variety of foods from the core food groups. Overall, eggs are an excellent way for pregnant women to meet their increased nutritional requirements during pregnancy. One serve of eggs provides almost 100% of the additional protein requirements and around a third of the extra kilojoules required during pregnancy and lactation. They also provide useful amounts of nutrients that assist in reaching the increased nutritional requirements of pregnancy such as zinc, folate and iron. Eggs are recommended as part of a healthy eating pattern that also includes wholegrain breads and cereals, fruits, vegetables, low fat dairy foods, lean meat, fish and poultry and unsaturated fats.

A recent study however found that a high intake of eggs (more than 7 eggs per week) was associated with increases in risk of gestational diabetes[401].

Example communication messages:

- Eggs are an excellent way for pregnant women to meet their increased nutritional requirements during pregnancy. One serve of eggs provides almost 100% of the additional protein requirements and around a third of the extra kilojoules required during pregnancy and lactation. They also provide useful amounts of nutrients that assist in reaching the increased nutritional requirements of pregnancy such as iron, folate and zinc.
- Eggs can be a particularly useful inclusion in the diet of pregnant vegetarian women as they provide the ideal complement of all essential amino acids needed for growth and development.
- One serving of eggs provides over 30% the daily requirements for vitamin B12 during pregnancy.
- One serving of eggs provides 100% of the additional vitamin B12 requirements during pregnancy.

- Regular inclusion of omega-3 enriched eggs in the diet of breastfeeding mothers can significantly improve the omega-3 status of the infants. This in turn may have significant benefits for development of visual and brain function.
- Eggs are one of only a few food sources of choline and provide more choline per kilojoule than most other foods. Choline is particularly useful in the diet of pregnant and lactating women. Eggs are therefore highly recommended at this time of life.
- Pregnant women are at risk of mild to moderate iodine deficiency. One serve of eggs provides 20% of the iodine RDI during pregnancy.
- Australian pregnant women often have low intakes of folate, iron and vitamin D. Eggs provide folate, iron and vitamin D and can therefore play a role in helping to meet these recommendations.

9.2 Children

Childhood is a time of growth and development so nutrition needs are particularly important during this time. Statistics from the Australian Institute of Health and Welfare indicate that in general, Australian children are in excellent or very good health [402]. However key concerns regarding children's health today are the growing rates of overweight and obesity, poor quality diets, as well as the impact of low physical activity levels and increasing energy intake from the diet. These concerns are reflected in the 2003 Dietary Guidelines for Children and Adolescents in Australia [11], highlighted below.

1. Encourage and support breastfeeding
2. Children and adolescents need sufficient nutritious foods to grow and develop normally
    - Growth should be checked regularly for young children
    - Physical activity is important for all children and adolescents
3. Enjoy a wide variety of nutritious foods
4. Children and adolescents should be encouraged to:
    - Eat plenty of vegetables, legumes and fruits
    - Eat plenty of cereals (including breads, rice, pasta and noodles), preferably wholegrain
    - Include lean meat, fish, poultry and/or alternatives
    - Include milks, yoghurts, cheese and/or alternatives. Reduced-fat milks are not suitable for young children under 2 years, because of their high energy needs, but reduced-fat varieties should be encouraged for older children and adolescents
    - Choose water as a drink. Alcohol is not recommended for children
5. Care should be taken to:
    - Limit saturated fat and moderate total fat intake. Low-fat diets are not suitable for infants
    - Choose foods low in salt
    - Consume only moderate amounts of sugars and foods containing added sugars
6. Care for your child's food: prepare and store it safely

Eggs fit well within these guidelines. They are not energy dense but are a highly nutritious food that can add variety to the diet. They provide essential nutrients for growth and development such as protein, unsaturated fats and vitamins and minerals, and are naturally low in salt. Eggs are easy to prepare and store, and have a stable shelf life of one month.

Overweight and obesity

The 2007 Children's Nutrition Survey of over 4000 Australian children aged 2-16 years reports 17% of children are considered overweight and 6% obese [9]. This is similar to the findings from the 2010 NSW School Physical Activity and Nutrition Survey (SPANS) which showed 17.1% were overwight and 5.8% obese[403] which is a reduction from the earlier 2004 SPANS report which showed the prevalence of overweight alone in NSW children may be as high as 26% for some age groups [404]. In 2011-2012 25.3% of children aged 5-17 years were overweight or obese, comprised of 17.7% overweight and 7.6% obese. The proportion of girls who were overweight or obese was higher than that of boys (27.1% compared with 23.6%)[405]. There has been no change in the proportion of children who were overweight or obese between 2007-08 and 2011-12[405].

As obesity and overweight are significant risk factors for heart disease, diabetes, arthritis and a range of other conditions, the government established a National Obesity Taskforce in November 2002. Children and families have been selected as key starting points to tackle the overweight and obesity epidemic. This taskforce developed the initiative 'Healthy Weight 2008' which is aimed at improving diet and lifestyle factors such as physical activity levels, in children and young adults. Additionally, focusing on preventative health in this age group is important as evidence suggests that laying the right health foundations during childhood can improve health and wellbeing later in life. This has prompted the government to work towards a National Agenda for Early Childhood, a collaborative program by all levels of governments to coordinate efforts to achieve the best outcomes for children [402,406]. Marketing strategies to improve the health of Australians include the Government's 'Get Moving' initiative, promoting physical activity specifically to children, and the 'Go for 2 & 5' fruit and vegetable promotion, both of which are part of 'Building a Healthy, Active Australia'. The 'Get Moving' campaign aims to encourage children and young people to get active for an hour or more a day. The Go for 2&5 campaign is designed to provide families with reliable, practical and consumer friendly information on the importance of healthy eating and physical activity to maintain a healthier lifestyle.

The New South Wales Government launched a $36 million initiative aimed at tackling obesity amongst children from 25 per cent to 22 per cent by 2016. The program also involves a social marketing campaign, a research centre, advice line, parenting program and the introduction of obesity medical and surgical clinics.

Figure 3 contains highlights from key reports regarding rates of obesity and overweight in children.

Figure 3: Health reports highlight the rising rates of overweight and obesity in Australia

- Overweight and obesity affects 25% of Australian children and adolescents Of this, 7% of children are obese[405]. Over the decade between 1985 and 1995, the prevalence of overweight children almost doubled, and the prevalence of obese children more than tripled [407].
- Rates of overweight and obesity increase with age and there is no indication this problem will taper off in the future.
- The food industry has received a great deal of criticism for its potential role in contributing to rates of overweight and obesity and is now developing more products that provide healthier options for children

In line with federal government initiatives, NSW, QLD and SA have had formal policies for healthy school canteens that guide the nutritional value and frequency of sale of foods and drinks through school canteens in place for some years. Commercial food and drink products need to meet the nutrient criteria in order to be sold in state school canteens.

Under the Australian Better Health Initiative, funding was provided for a National Healthy School Canteens Project which resulted in the development of a National Healthy School Canteens Guidelines for healthy food and drinks supplied in school canteens[408] in 2010.

Current recommendations regarding healthy eating for children state that the majority of food should be provided from the five core food groups of cereals, vegetables, fruit, milk, and meat or alternatives [11]. Foods of high energy, low nutrient value such as cakes and pastries, confectionery, potato crisps and soft drinks should make only a small contribution to energy intake [11]. However on a daily basis, many 2 to 18 year olds are failing to include foods from one or more of the five core food groups while consuming significant quantities of high energy, low nutrient value foods [384].

Government efforts to promote core foods to children have been intensified with recent debate about the appropriateness of television advertising of 'junk' foods to children. Eggs are a core food within the 'meat and alternatives' group of the Australian Guide to Healthy Eating, fitting well with government efforts to promote healthy eating habits to children. More information about overweight and obesity can be found in Section 2 of this report.

Allergies and intolerances

Food allergies involve a severe reaction by the immune system to the protein component of a food. The most common allergens are egg, milk, peanuts and other nuts, soy and wheat [409]. Food allergy affects between five and eight percent of children under the age of five years but most of them outgrow their allergy prior to commencing school [409]. There is general agreement that food allergy is highest in infancy (up to seven and a half percent), falling rapidly after the age of three years to one to two percent [409]. According to the Department of Immunology at the Royal Prince Alfred Hospital in Sydney, food allergies are increasing in Australia.

Unlike food allergy, food intolerance does not involve the immune system and reactions tend to be less severe, developing more slowly and to a broader range of foods. Approximately 10 percent of the Australian population are estimated to experience food intolerance [409]. Common triggers of intolerances include natural and artificial substances in foods, particularly salicylates, amines, glutamates, preservatives and colours [409].

While eggs are one of the most common allergenic foods they are rarely involved in food intolerance reactions.

Guidelines regarding egg intake for children with and without egg allergy are outlined in Section 10 of this report.

Diet Quality

The 2007 Australian Children's Nutrition and Physical Activity Survey [9] was conducted among over 4000 children and teenagers from all around Australia to provide information about the dietary intake and body size and weight of children aged 2-16 years and activity patterns of children aged 5-16 years.

While data from the previous nutrition surveys show Australian children may be falling short of optimal vitamin and mineral intakes [384], the 2007 survey shows children generally consume sufficient energy and key nutrients to maintain good health. However the rates of obesity, sedentary behaviours and inadequate intake of foods from key food groups remain areas of concern. Additionally, intakes of calcium were significantly lower than estimated average requirements (EARs) in children. Fifteen percent of girls aged 4-8 years did not meet the calcium EAR, along with 55% of girls and 35% of boys aged 9-11 years.

Sodium intake exceeded the recommended upper level of intake for children of all ages, and around 40% of children aged 3-4 years had reported kilojoule intakes that exceeded the upper limit of the estimated energy requirement range. Only 5% of children met the guideline for vegetable intake if potatoes were excluded from the analysis (approximately 15% met the recommendation when potatoes were included).

Intakes of vitamins D and E were also found to be lower than the adequate intake values (AIs) for all ages. Vitamin D intake was 2.7 to 3.4mcg per day, less than the AI of 5mcg, and vitamin E was also lower than recommendations however this may be due to limited data on the vitamin E content of the Australian food supply.

Figures from the 2004 NSW Schools Physical Activity and Nutrition Survey (SPANS) show that between 65 and 78% of children in years 6 and 8 eat fish less than once per week, with 26-37% eating no fish at all [404]. Because fish is an important dietary source of the long chain omega-3 fatty acids, many children are estimated to have an inadequate intake of this essential fatty acid [410]. This is supported by data published in 2011 which showed just 6% of children aged 5-16 years meeting the suggested dietary target for long chain omega 3 fatty acids per day[411]. A serve of eggs contains 114mg of long chain omega-3 fatty acids, which represents 163-207% of the adequate intake (AI) for children aged 4-13 years [2].

Inadequate nutrient intakes may be due to a number of factors including fussy eating, vegetarian eating patterns or food allergies. Inappropriate food choices also play a role, as shown by the regular consumption of low nutritional value foods like potato crisps, corn snacks and confectionery [384]. Higher intakes of energy dense, nutrient poor foods are associated with lower intakes of key nutrients, indicating snack foods can displace more nutritious foods in the diets of children [412].

Eggs are an ideal food for inclusion in children's diets as they are nutritious and provide useful amounts of vitamin A, iron, riboflavin, zinc, iodine, folate and long chain omega-3 fats. Eggs are also a good source of protein for children to support growth during this time [11].

Vegetarian children who exclude eggs and dairy products may experience difficulty achieving sufficient amounts of vitamin B12, iron, calcium and zinc [413]. Their diets require careful planning and sometimes supplementation with additional quantities of these essential nutrients [413]. There is some evidence that vegan children do not achieve their full growth potential even if they do not show clinical evidence of nutrient deficiencies [5]. Eggs are a particularly useful inclusion in the diets of vegetarian children in order to assist in meeting vitamin B12, iron and zinc intakes in particular.

Zinc

Children require zinc for building and developing muscle tissue and internal organs as well as for immune function. Egg yolk is a source of zinc with two eggs providing 0.5mg of zinc, 13% of the RDI for 4-8 year olds and 8% of the RDI for 9-13 year olds.

Folate

Folate is required for growth and maintenance of healthy cells, particularly important functions for children. Eggs are a good source of folate for this group with two eggs containing 97µg of folate (49% of the RDI for 4-8 year olds and 32% of the RDI for 9-13 year olds). The National Nutrition Survey showed eggs provide approximately 1.6% of the average daily intake of folate for children aged 2-11 years [384].

Vitamin A

Vitamin A is essential for growth, cell differentiation and is integral in eyesight development. Two eggs contain 239µg of vitamin A, representing 60% of the RDI for children aged 4-8 years and 40% of the RDI for children aged 9-13 years. Eggs are therefore a particularly useful source of vitamin A in the diet of children and on average, egg products and dishes contribute 3% of the daily vitamin A intake for children aged 2-11 years [384].

Physical activity and screen time

The Children's survey showed 31% of children and teenagers did not meet physical activity guidelines of one hour of activity per day, and 67% exceeded the daily screen time recommendation of two hours of viewing [9].The 2010 SPANS study also reported that 19.3% of primary school children consumed dinner in front of the television 5 or more days per week[403].

Example communication messages:

- Eggs are a nutritious food for children, fitting well within the Dietary Guidelines for Children and Adolescents.
- Eggs provide useful amounts of nutrients to improve the nutrient content of children's diets.
- One serve of eggs provides around a third of the recommended dietary intake of folate for children. Folate is essential for the growth and maintenance of healthy cells.
- One serve of eggs provides around half the recommended dietary intake of vitamin A for children. Vitamin A is essential for growth and eye health.
- Eggs are a valuable source of omega-3 fatty acids which are commonly lacking in the diets of Australian children.

9.3 Teenagers

Nutrition requirements during adolescence are high to fuel rapid growth and development, however adolescents often have irregular eating patterns, with a tendency to skip breakfast, graze constantly, have a high intake of snacks, confectionary and soft drinks, experiment with different diets, and make poor food choices [5].

Market research shows that convenience, more than nutrition, is the first priority in food choice for young Australians [414]. Considering eating habits, developed in childhood and adolescence, persists into adulthood then establishing healthy eating habits at this age is essential for long-term health [5].

Reports also show that as a result of changing work, lifestyle and household structures in Australia, children and teenagers have more independence after school and more buying power [415].

Nutrient Intakes

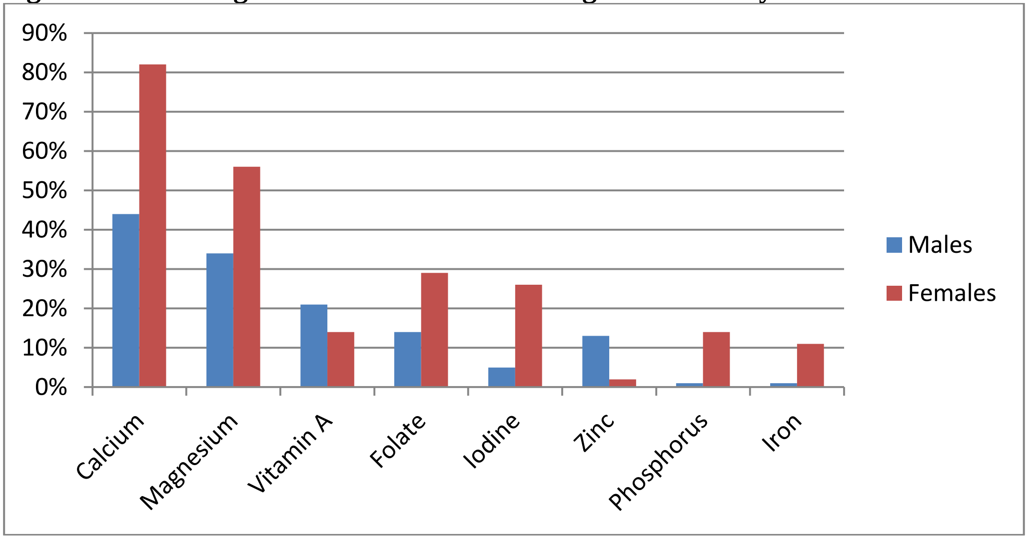
Results of the 2007 Children's survey [9] show intakes of key nutrients are generally inadequate in teenagers. Teenagers aged 14-16 years did not meet EARs for vitamin A (21% of boys and 14% of girls), folate (14% of boys and 29% of girls), calcium (44% of boys and 82% of girls) and magnesium (34% of boys, 11% of girls). In addition, 13% of teenage boys did not meet EARs for zinc, while teenage girls fell short of phosphorus (14%), iodine (26%) and iron (11%).

Because most EAR values are approximately 20% less than recommended dietary intakes (RDIs), this means even greater numbers of teenagers would be falling short of optimal intakes. For instance, the RDIs for iodine and iron are significantly higher than the EARs. Average iron intake was 11.1mg for girls aged 14-16 years, which met the EAR of 8mg but was 26% lower than the RDI of 15mg. Similarly, iodine intake was 118.8mcg, exceeding the EAR of 95mcg but representing only two thirds of the RDI of 150mcg.

Intakes of vitamins D and E were also found to be lower than the adequate intake values (AIs) for all ages. Vitamin D intake was 2.8 to 4mcg per day, less than the AI of 5mcg, and vitamin E was also lower than recommendations however this may be due to limited data on the vitamin E content of the Australian food supply.

Of concern is that less than 2% of teenagers met the guideline for daily fruit and vegetable intake, and sodium intake exceeded the recommended upper level of intake.

Figure 4: Percentage of adolescents not meeting EARs for key vitamins and minerals [9]



As shown in the figure, key nutrients of concern in adolescents' diets are calcium, magnesium, vitamin A, folate, iodine, zinc (males only), and iron and phosphorus (females in particular). With the exception of calcium and magnesium, eggs provide useful amounts of these nutrients and could therefore play a useful role in meeting nutritional requirements in adolescence.

Overweight and obesity

Like younger children, the level of overweight and obesity in this age group remains a significant problem.In 2011-2012 25.3% of children aged 5-17 years were overweight or obese, comprised of 17.7% overweight and 7.6% obese. The proportion of girls who were overweight or obese was higher than that of boys (27.1% compared with 23.6%)[405]. On a positive note, there has been no change in the proportion of children who were overweight or obese between 2007-08 and 2011-12 suggesting a plateuing of the problem.

Being overweight or obese substantially increases the risk of acute health problems and chronic disease. Studies among children and teenagers in NSW show that overweight and obese students are more likely than those who are not overweight to have risk factors for diabetes, cardiovascular disease and liver disease. Alarmingly more than 20% of overweight or obese boys were found to have two or more chronic disease risk factors [404].

Eggs are a highly nutritious food with one serve (2 eggs) containing 581kJ, around the same amount as two thin slices of bread. As eggs are high in protein, they may also increase satiety therefore contributing to a greater ability to manage total food intake over the day [416]. See Section 2 of this report for further information and evidence about the role of eggs and protein in weight management.

Dieting

Common dieting practices among teenage girls involve the reduction or elimination of key food groups [417], such as red meat and/or breads and cereals. These food groups together contribute nearly half of the daily iron intake [384]. Bread alone contributes approximately 12% of the daily iron intake for girls aged 12-18 years [384]. The 2007 Children's Survey found that girls aged 14 to 16 years had an intake of approximately 11mg of iron, below the recommended 15mg for this group [9]. Vitamin B12 and zinc may also be limited in diets devoid of meat. Eggs contain a variety of nutrients that may be limited in teenage diets. One serve of eggs provides 1.7mg of iron (11-15% RDI), 0.5mg of zinc (4-7% RDI) and 0.8µg of vitamin B12 (33% RDI).

Breakfast

Data from 1997 suggested around 15 percent of teenage boys and 35 percent of teenage girls skip breakfast two or more days a week [418]. Newer figures from 2010 SPANs survey found that only 73.2% of high school boys and just 57.6% of high school girls eat breakfast on a daily basis[403] which suggests the practise of breakfast skipping is becoming more common in this age group. Research shows breakfast eaters are more able to control their weight, have better nutrient intakes, have better concentration levels and are better able to perform mental tasks throughout the morning [419]. In particular, breakfast consumption has been recently associated with improved mathematical thinking[420]. Improving teenage breakfast eating habits is important to ensure good health, optimal mental and physical performance and for long-term establishment of healthy eating habits that assist weight control.

While eggs are often eaten as a breakfast food, the Third American Health and Nutrition Examination Survey (NHANES III) showed that eating cereal (ready-to-eat or cooked cereal) or quick breads for breakfast was associated with significantly lower body mass index compared to skipping breakfast or eating meats and/or eggs for breakfast [421]. Note in this study however that meat and eggs were included together so the effect of other foods eaten in conjunction with eggs was not accounted for. The researchers also did not adjust for dietary fat intake, which could have confounded the results. However, it has also been shown that carbohydrate-rich breakfasts have better effects on hunger, satiety and mental performance than fat-rich breakfasts [422]. On the other hand, eggs have been shown to have a 50% greater satiety index than ready-to-eat breakfast cereals or white bread, and when eaten for breakfast, eggs can reduce the amount of energy (kilojoules) consumed at lunch by 29% [416]. Research has also shown that eating a variety of foods at breakfast is associated with better mental performance in adolescence[423].

Snacks

Sixty percent of teenagers eat 5 to 6 times a day indicating snacks constitute an important part of their food intake [418]. High intakes of confectionary and salty snack foods may be displacing more nutritious foods in the diet, contributing to lower than ideal intakes for many nutrients [412]. Eggs may have a useful role to play as a nutritious snack food for adolescents.

Eggs are a highly nutritious food that can play an important role in the diets of teenagers. Eggs are recommended as part of a healthy eating pattern that also includes wholegrain breads and cereals, fruits, vegetables, low fat dairy foods, lean meat, fish and poultry and unsaturated fats.

Example communication messages:

- Eggs provide a broad range of important nutrients essential to meet the needs of growing teenagers.
- Many teenagers fall short of vitamin A, folate, iodine, zinc, iron and phosphorus requirements. Eggs provide useful amounts of these nutrients and may help boost intakes closer to RDI levels.
- Due to the wide range of nutrients found in eggs, they are a particularly useful inclusion in the diet of teenagers who may be following special diets.
- Many teenagers skip breakfast and due to the variety of nutrients and protein found in eggs, they can provide a nutritious start to a teenager's day.

9.4 Vegetarians

Increasing numbers of people are choosing to follow vegetarian eating patterns. Although only 5-6% of females and 1-3% of males claim to be vegetarian[418,424], a 2010 Newspoll survey found that 7 out of 10 Australians are eating more plant-based meals than previously, in the belief that eating less meat and more plant foods improves overall health[425]. Previous estimates show vegetarianism is more popular amongst women, with the highest prevalence of vegetarianism being in women aged 19-24 years [426].

The health benefits of a vegetarian eating pattern rely heavily on achieving a nutritionally balanced diet relative to the individual's needs [427]. As they consist of predominantly plant based foods, vegetarian eating patterns can offer a number of benefits including lower levels of saturated fat, and higher levels of fibre, magnesium, potassium, folate, antioxidants such as vitamins C and E and phytochemicals compared to meat-containing diets [111]. Research has shown that a well planned vegetarian diet can meet nutritional needs for good health and may reduce the risk of cancer, cardiovascular disease, metabolic syndrome, insulin resistance, type 2 diabetes, hypertension and obesity[425]. A 2006 review also showed that vegetarians were 20 per cent less likely to be overweight than meat eaters [428]. An Australian study of young women showed vegetarians and semi-vegetarians (those that excluded only red meat) had lower body mass indexes than non-vegetarians and tended to exercise more [429]. Recent data also suggests vegetarians live longer than non-vegetarins (on average 9.5 years longer for men and 6.1 years longer for women)[430].
However inadequately planned vegetarian diets can result in insufficient intakes of vitamin B12, iron, calcium and zinc in particular [413]. Vegetarian diets may also be low in vitamin D and meeting recommendations for long chain omega-3 fatty acids is also difficult unless the diet is supplemented[425,431]. Choosing nutrient dense foods such as eggs and dairy (lacto-ovo vegetarians), nuts, seeds, legumes and green leafy vegetables is therefore important to provide sufficient vitamins, minerals, essential amino acids and essential fatty acids.

Energy and protein

The kilojoule intake of vegetarians is similar to non-vegetarians [359] but diets tend to be bulky [432], which can result in lower energy and nutrient intakes in infants and young children with smaller appetites [413]. Eggs are ideal in this situation for ovo-vegetarians as they are small but nutritionally dense. Lower rates of growth in the first few years of life have been recorded in some vegan children [427] but lacto-ovo-vegetarian children have similar energy intakes and growth patterns to omnivores [433-435]. As lacto-ovo-vegetarian diets include eggs and dairy foods, these foods may be attributed to the improved energy intakes and growth patterns in this group of vegetarian children.

The total protein content of a vegetarian diet can be significantly lower than an omnivore diet [10]. Due to a smaller variety of protein containing foods eaten by ovo-vegetarians, poor food choices can result in an insufficient intake of essential amino acids, particularly methionine and lysine [7].

Although recent evidence suggests that while vegetarian diets may provide less protein than a non-vegetarian diet, vegetarians are still able to meet protein requirements quite easily[436]. Additionally, the protein digestibility and lower biological protein value of many plant proteins may result in deficient dietary intakes of essential amino acids in ovo-vegetarian diets [7]. It has been suggested that due to the decreased protein bioavailability of vegetarian diets, that total protein requirements should be higher for vegetarians compared to omnivores if low amounts of animal protein are consumed [437] or if single plant sources are relied upon for protein [436]. Eggs are ideal as they supply all essential amino acids in a highly bioavailable form.

Essential fatty acids

Concern has been expressed about the balance of essential fatty acids found in vegetarian and vegan diets, which can be especially high in omega 6 fatty acids [206,438]. Data suggest that vegans consume about 1.15g/day of alpha-linolenic acid and no long chain PUFAs [203].However, there is no convincing evidence that vegetarians or vegans experience adverse effects as a result of a low dietary intake of EPA and DHA[439]. Vegetarians consume about 1.42g/day of ALA and 30mg/day of arachidonic acid and 20mg/day of DHA. The source of the long chain essential fatty acids is mostly from eggs. Additionally the ratios for omega 6 to omega 3 fatty acids were 12.9 for the ovo-vegetarians and 18.7 for vegans, which is significantly higher than both moderate meat eaters and high meat eaters. A high ratio of omega 6 to omega 3 fatty acids may inhibit production of other long chain fatty acids (EPA and DHA) and potentially impair development of new tissue, especially brain and retinal tissue, and production of eicosanoids [206]. As fish and red meat are not eaten, EPA and DHA become virtually absent from vegetarian and vegan diets [427,440]. As a result, recently it has been suggested that in order to compensate for the lower levels of EPA and DHA in the tissues, vegetarians require double the recommended adequate intake (AI) of the plant type of omega-3 (ALA) compared to non-vegetarians [439,441]. Vegetarians with increased needs or reduced conversion ability may receive some advantage from DHA and EPA supplements derived from microalgae. A supplement of 200-300mg/day of DHA and EPA is suggested for those with increased needs, such as pregnant and lactating women, and those with reduced conversion ability, such as older people or those who have chronic disease (eg, diabetes)[439].

The difficulty in meeting omega 3 fatty acid recommendations highlights the vital role of foods such as eggs that can provide omega-3s in a vegetarian diet, contributing an average of 114mg of long chain omega-3 fatty acids per serve, which represents 71-127% of the adequate intake (AI) [2]. Eggs are the only vegetarian source of DHA, containing 104mg per serve. Omega-3 enriched eggs provide higher levels; however, to be acceptable in a vegetarian diet, the additional omega-3 needs to arise from plant sources, such as flaxseed.

Iron and vitamin B12

Low serum levels of vitamin B12 have been reported in adult vegan and vegetarians [442] and low iron levels in young Australian vegetarian and semi-vegetarian women [429]. Inadequate intakes of iron and B12 can lead to anaemia, which can impair the immune response and inhibit physical performance [443]. Anaemia is more frequent in vegetarian women, especially during pregnancy [388]. At this time, low vitamin B12 and iron intakes, coupled with low maternal stores, and lower levels secreted in breast milk, increases the risk of deficiency in children born to vegetarians [444]. Much of the B12 present in common vegetarian protein sources such as spirulina, nori, tempeh, and miso has been found to be an inactive analogue rather than the active vitamin, and may even compete with the active form for uptake [445,446]. Eggs are recognised as a source of bioavailable, active vitamin B12. Current studies are underway also looking at enriching eggs with iron, which could further benefit vegetarians. One serve of eggs provides 40% of the RDI for vitamin B12 and 14% of the RDI for iron.
Vegetarians have good intakes of folic acid, which may mask the megaloblastic anaemia of vitamin B12 deficiency [427].

Vegetarians must therefore be aware of the importance of adequate vitamin B12 intake and anyone who significantly limits intake of animal-based foods, require vitamin B12 fortified foods or supplements.

Other nutrients
Vegetarians tend to have similar or greater dietary intakes of most minerals except iodine, calcium (vegans only) and possibly selenium and like most Australians, vitamin D. Vegetarians must also take extra care to ensure adequate zinc because of its low bioavailability from plant-based sources [427]. Some vegetarians have diets that are significantly below recommended intakes for zinc [111] and this can be a concern as zinc deficiency can impair the immune system and reduce fertility. One serve of eggs contains useful amounts of zinc (4% RDI) and selenium (59% RDI).

Example communication messages:

- Eggs can play a significant role in a vegetarian diet due to the provision of high quality protein, vitamin B12 and iron, nutrients that are often low in a vegetarian eating pattern.
- Eggs can be a particularly valuable source of omega-3 fatty acids in a vegetarian diet as intakes are often particularly low in this group of people. Omega-3 fatty acids are essential for the health of the heart and blood vessels.
- One serve of eggs contains useful amounts of selenium (59% RDI), vitamin B12 (40% RDI) and iron (14% RDI), all nutrients that can be low in a vegetarian diet.

9.5 Sports people

The latest National Health Survey results[405], released in October 2012 showed that while most Australians aged 15 years and over had undertaken exercise in the week prior to the survey, the overall level of this activity was low. Taking into account the intensity, duration and frequency of individuals' physical activity, 66.9% of Australians were either sedentary or had low levels of exercise in the week prior to interview (comprised of 35.4% sedentary and 31.5% low levels of exercise). However, this is a decrease from 2007-08 when the proportion of people who were sedentary or had low levels of exercise was 71.6%.

While many Australians are inactive, the proportion that are very active have different nutritional requirements to the rest of the population. They require more carbohydrate, fluid, protein, iron and calcium to ensure maximum performance and optimum recovery after a training session or competition.

Nutrition issues
It is well recognised that carbohydrate is extremely important in the diet of athletes to maintain muscle glycogen levels, and thereby fuel performance during training and competition [443]. Research shows low GI carbohydrate foods may be useful for some athletes. However, Sports Dietitians Australia recommends caution in application of GI to the diets of athletes [447]. Manipulating the GI of meals in sports nutrition may be useful to optimise carbohydrate availability for exercise. This is particularly useful for sports or activities involving prolonged, moderate intensity exercise. The addition of protein or fat to a carbohydrate-containing meal lowers the GI of that meal. Eggs fit well in the diet of most athletes due to their nutrient density and versatility. A meal of eggs on toast or eggs mixed with rice or pasta provides a good range of the essential vitamins, minerals, carbohydrate and protein needed for optimal performance.

High quality dietary protein is essential for athletes. To develop, maintain and repair muscle tissue, strength and speed athletes require more protein as a percentage of energy, than endurance athletes [443]. Protein recommendations for athletes may differ depending on body size, weight and body composition goals, the sport participated in, and gender [16]. An athlete may need an increased protein intake because of the need to repair exercise-induced micro-damage to muscle fibres, the use of small amounts of protein as an energy source, and the need for additional protein to support gains in lean tissue mass [16]. Protein requirements for endurance athletes are 1.3-1.6 per kilogram body weight a day and for resistance athletes are 1.2 – 1.7g per kilogram body weight a day[448].

A study [17] examined the effect of consuming different amounts (0, 5, 10, 20 and 40 grams) of egg protein after resistance exercise on muscle building. Muscle and albumin protein synthesis increased in relation to the amount of egg protein consumed, however reached a plateau at 20 grams. Above this level, the protein was used for energy.

Another study [449] reinforced these findings and showed a moderate serving of protein in a single meal (around 30 g) is the best for muscle building, and intake beyond 30 g in a meal does not further enhance the stimulation of protein synthesis.

A 2012 study in female athletes, however, did not show any benefit of a 15g egg white protein supplement on body composition or muscle strength[450]. Longer studies or higher protein intakes may be required to show an effect of egg white supplementation.

Eggs represent a source of highly bioavailable protein for athletes and provide all essential amino acids. Athletes consuming limited energy (kilojoules) may require manipulation of the diet to ensure optimum protein intake and eggs may play a particularly valuable role in this instance.

Iron is particularly important for serious athletes, especially if female or vegetarian where dietary levels can already be low compared with RDIs. Iron deficiency results in fatigue and reduced performance due to decreased oxygen carrying capacity. Iron depletion is common in athletes, and if it progresses to anaemia can impair performance substantially. The prevalence of iron deficiency anaemia in athletes is estimated to be around 3%[448].

Athletes often have a high red blood cell turnover, so an increased intake of vitamin B12 may be beneficial for regeneration of new red blood cells. Vitamin B6 and folate are also required for formation of red blood cells and an increased intake may benefit athletes. Eggs are an appropriate source of these nutrients.

Evidence is emerging that supplemental dietary antioxidants may reduce oxidative stress and skeletal muscle damage associated with strenuous exercise [451]. Results of these studies, however, have been conflicting and inconsistent so definitive recommendations about antioxidant use (in terms of supplements) in sports cannot currently be made[448]. Currently, the evidence from epidemiological studies and the limited number of studies conducted on athletes favours high intakes of antioxidants from food sources, rather than supplements[448]. Despite the lack of evidence for antioxidant supplement use, evidence suggests athletes do have higher anti-oxidant requirements to help reduce oxidative damage. A diet that contains anti-oxidant nutrients in amounts that exceed the RDI by as much as threefold is recommended[448]. Eggs contain vitamins A, E and selenium, which have antioxidant functions and therefore may offer further nutritional advantages as part of an athlete's diet.

Example communication messages:

- Protein requirements are often higher than average for athletes and eggs provide a valuable source of high quality protein for this group.
- Eggs provide a range of valuable nutrients in the diets of sports people including iron, folate and vitamin B12, all required for healthy red blood cells that carry oxygen to the working muscles.
- Eggs provide a range of valuable antioxidants which may assist recovery after exercise by reducing muscle and cell damage.
- Evidence suggests sports people have increased antioxidant requirements. Eggs provide a range of antioxidant nutrients.

9.6 Older Adults (65+ years)

People aged 65 and over are family oriented, cost conscious, have strong traditional cooking skills though are less adventurous with food, and eat out less than other age groups [415].

Nutrition plays a significant role in the maintenance of health throughout the normal ageing process. Eating well becomes even more important with age as it plays a significant role in the maintenance of good health and in the ability to lead an active and healthy lifestyle. In addition, eating a good quality diet has been linked to living a longer life [452]. Meals add a sense of security, meaning, and structure to an older adult's day, providing feeling of independence and control and a sense of mastery over his/her environment[171]. Older Australians are faced with a range of nutrition issues that challenge diet quality such as reduced appetite, poor dentition, limited access to food and reduced income. The most recent National Nutrition Survey found that people over 65 are the least likely of all Australians to want to change their diet [418] however around 70 percent of deaths in Australians aged 65 to 84 are due to cardiovascular disease or cancer, both of which have diet related risk factors [453]. Fifty percent of deaths in the 65-69 age group are diet-related. For older Australians, the most prominent health conditions in terms of death and hospitalisation are heart disease, stroke and cancer [454]. Despite these figures, Healthy life expectancy is increasing for older Australians. In 2009, at age 65, females could expect to live a further 16.1 years without requiring assistance with core activities, and males could expect another 15.2 years without requiring assistance[405].

Intake of key vitamins and minerals are commonly low in the diets of older Australians [384] most likely due to overall decreased food consumption. Common sense nutrition advice that is easy to follow is most appealing to this population [414].

There are a number of age-related changes that influence nutritional requirements and become significant for people over 65 years [14]. A decreased immune function results in an increased need for vitamins B6, E and zinc. Decreased gastric acid production leads to an increased need for vitamin B12, folic acid, calcium, iron and zinc and an increase in oxidative stress status results in an increased need for carotenoids, vitamin C and vitamin E. Sunlight is less efficiently converted into vitamin D in older people [2]. In addition, immobile elderly spend less time outdoors, leading to an increased need for food sources of vitamin D. One serve of eggs provides vitamin B12 (33% RDI), folate (24% RDI), iron (21% RDI), zinc (4-6% RDI), vitamin E (24-34% RDI) and vitamin D (5% AI) [14].

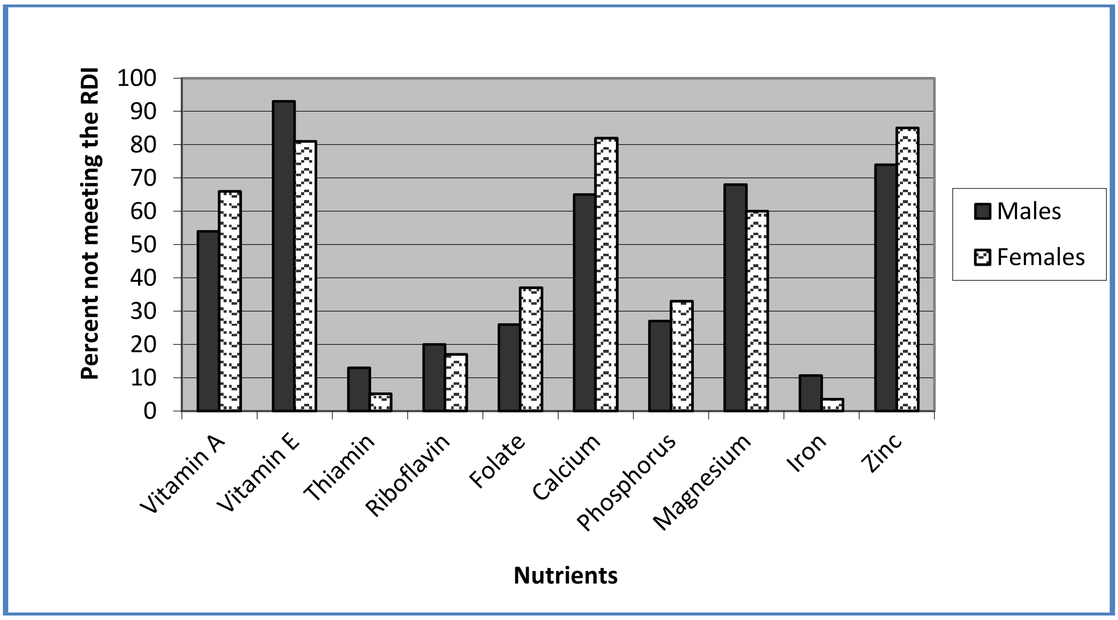
Body composition also changes with increasing age, with a particularly notable reduction in skeletal muscle mass and other body proteins such as organ tissue, blood cells and immune factors [6].

Evidence suggest the regular performance of resistance exercise and the habitual ingestion of adequate amounts of dietary proteins from high quality sources are two important ways for older people to slow down the progression of the age-related loss of skeletal muscle mass and function, and, eventually to treat sarcopenia[455]. Current evidence also suggests vitamin D and calcium as well as the acid-base balance of the diet may play an important role in maintaining muscle mass in older adults[455]. The protein RDI for adults aged 70 years and over (81grams of protein per day for older men and 57g for older women) [2] is around 25% higher than the protein needs of younger adults due to increased protein requirements with age. Research in an American population shows approximately 30-40% of men and women over 50 years of age consume less than the recommended amount of protein[456]. Regular consumption of high quality proteins can be challenging for older adults with limited resources, reduced appetite, and physical and environmental limitations[171]. Inadequate protein intakes contribute to increased skin fragility, decreased immune function, poor wound healing and longer recovery times [6], highlighting the importance of maintaining adequate protein intake in older adults.

Nutrition Issues

The National Nutrition Survey shows those aged 65 years and over eat less than the recommended minimum number of serves from each of the food groups [198], and have low intakes of vitamins and minerals [384]. The 1995 National Health Survey shows that only approximately 20% of adults in this age group consume the recommended five serves of vegetables each day [457]. Self-reported fruit consumption also indicates that more than 35% of the population over 55 years consumes less that the recommended 2 serves of fruit each day [457]. This, combined with the fact that many older adults have increased nutrient requirements and decreased food intake means nutrients that are commonly low in the diet of older Australians include fibre, calcium, vitamins A, E, B6, B12, folate, vitamin C, iron, magnesium and zinc [384 32 458]. A Victorian study conducted between 1997 and 1999 also showed that older Australians are at risk of nutritional deficiency [32], the results of which are consistent with dietary data from the National Nutrition Survey of 1995. This survey found many older Australians have nutrient intakes below the recommended dietary intake (RDI) (Figure 5).

Figure 5: Percentage of older Australians (aged >64 years) with nutrient intakes less than the RDI [32]



As shown above, vitamin E, zinc, calcium, magnesium and vitamin A intakes are of particular concern with the majority of older Australians not meeting the RDI for these nutrients. Other recent evidence has shown that older Australians with the lowest intake of vitamin D and vitamin B12 may also be at risk of becoming deficient in these nutrients [34,100]. Results from the 2005 Blue Mountains Eye Study, an Australian study of 2,895 participants aged 49 years and older, showed that 23% had serum vitamin B12 levels below 185pmol/L, indicating they have, or are at risk of, vitamin B12 deficiency [100]. More recent data from one Australian study of free-living elderly women (70-85 years) found they had suboptimal intakes of key vitamins and minerals including foltae, vitamin E and calcium[84]. Research also suggests that older people who primarily stay indoors are at a high risk of vitamin D deficiency. Studies have shown that up to 80% of women and 70% of men living in hostels or nursing homes in Victoria, New South Wales and Western Australia were deficient in vitamin D [34].

Health issues

Overweight, high blood pressure and high cholesterol are significant health issues that affect older adults and are risk factors for chronic diseases such as Type 2 diabetes and heart disease. Overweight and obesity rates peak in people over 55 until 65 years, after which they plateau and then decline after 74 years of age[405]. Type 2 diabetes occurs in 14-16% of individuals over 65 years of age [459]. High blood pressure is also a risk factor for stroke, and increases with age, especially in men [453]. To combat this problem, the dietary guidelines for older Australians advise choosing foods low in salt and using salt sparingly [14]. One serve of eggs provides only 141mg of sodium.

Two thirds of older adults have high cholesterol, which is another risk factor for heart disease [460]. Omega 3 fatty acids are highly beneficial for heart health and should be encouraged with this group. Two eggs provide 180mg omega-3s, 114mg of which is the long chain DHA/DPA.

Another relevant health issue for older adults is eye health. There is evidence that high-dose supplementation with vitamin A, antioxidants and zinc may reduce the amount of visual degeneration in the elderly [461]. There is also evidence indicating a role for the antioxidants lutein and zeaxanthin in the prevention of age-related macular degeneration [147,163], the leading cause of blindness in Australians aged over 50 years. For people aged 54 years and over, one serve of eggs provides bioavailable vitamin A (27-34% RDI), 0.53mg of the antioxidants lutein and zeaxanthin, vitamin E (24-34% RDI), and selenium (59-68% RDI), and zinc (4-6% RDI).

Arthritis affects over 50% of the population aged over 65 years [402], while over half of women and one third of men over 60 years will suffer a fracture due to osteoporosis [460]. Calcium is required to prevent development and progression of osteoporosis and is especially important for elderly who participate in less physical activity. Vitamin D is also important for bone health and eggs are one of only a few significant food sources of this vitamin.

Decreased taste sensitivity and hunger signals in older people can lead to decreased food intake. Low fat diets are not recommended for convalescing or frail older people as they may contain inadequate energy (kilojoules). Despite this, the Australian Bureau of Statistics has found that one quarter of people over 65 are on a fat modified diet [418]. Older adults may unnecessarily be avoiding eggs because of their fat and cholesterol content.

Zinc status is often low in older adults due to decreased bioavailability and reduced overall food intake [458]. Zinc deficiency can increase susceptibility to infection, decrease taste sensation and appetite, and lead to poor wound healing and night blindness, all of which jeopardise health in the elderly. Eggs make a useful contribution to zinc intakes of older adults.

It is common for this age group to have a reduced appetite and therefore reduced food intake. This can lead to severe reductions in body weight and is sometimes referred to as the 'anorexia of aging' [427]. Changes in the gastrointestinal tract such as decreased number of taste buds and reduced muscle tone and motility of the intestine can lead to decreased appetite and enjoyment of food [462].

Poor dentition can be a key factor in undernutrition in this age bracket. A survey in the UK of nearly 1700 elderly people over 65 found that those who had better oral health had better nutritional status [463]. A 2012 Australian study also found those with lower chewing ability had lower compliance with dietary guidelines in relation to fibre, sugar, fat and salt[464]. Loss of teeth and poorly fitting dentures significantly reduce chewing ability [5]. Reduced salivary flow and difficulty in swallowing is also a common problem [5]. Soft, moist foods may be tolerated more easily so foods such as eggs can play a key role because they are soft, palatable and easy to chew.

Relevant social issues impacting on diet and nutrition

Some older adults may find difficulty accessing shops or transport for food, shopping less often than other groups and purchasing foods that keep well and can be easily transported.
Social and psychological factors significantly affect the nutritional status of this population. Two factors most consistently linked with poor dietary intake in old age are low socioeconomic status and, among older men, living alone. Other common problems include loneliness, social isolation, bereavement, memory loss, and depression [5]. It has been hypothesised that a diet low in omega 3 fatty acids may predispose an individual to depression [458], suggesting another role for omega-3 enriched eggs. Polypharmacy is also common among older adults and many drugs limit food intake by decreasing appetite, producing nausea, disturbing gastrointestinal system, and impairing taste or smell [5].

Due to the variety of nutrients found in eggs, they are an ideal food to include the diets of older adults. Eggs are especially suitable for this population group because they are easy to transport and store, are comparatively cheap as a source of protein, and are consistently available in manageable quantities by the dozen or half dozen. If bought fresh, eggs have a relatively long shelf life of one month. Figures from the National Nutrition Survey show 16% of adults aged 65 years and over consumed eggs and egg dishes on the day of the survey [465]. In addition, egg consumption data from the Australian Bureau of Statistics shows that older couples and singles are the highest egg consumers in Australia, with over 35% of this population group purchasing eggs.

Example communication messages:

- Due to age related changes in the functioning of the digestive system, nutrient requirements can be higher in older Australians. Due to the variety of nutrients found in eggs, they can play a particularly valuable role in the diet of this group.
- The majority of older Australians do not meet the RDI for vitamins A and E and eggs can provide a useful contribution to meeting requirements with one serving providing 27-34% RDI for vitamin A and 24-34% RDI for vitamin E.
- Due to their soft texture, eggs may be a particularly suitable food in the diets of frail elderly.
- The incidence of heart related problems are highest in older Australians. Eggs are a source of omega-3 fatty acids, which have been shown to have benefits for the heart and blood vessels.
- Eggs contain the antioxidants lutein and zeaxanthin, which have been shown to be associated with lower rates of age-related macular degeneration (AMD). AMD is the leading cause of blindness in older Australians.

10. Role of Eggs in Weight Management

10.1 Background

The World Health Organisation defines obesity as "a disease in which excess body fat has accumulated to an extent that health may be adversely affected. However, the degree of excess fat, its distribution within the body and the associated health consequences vary considerably between obese individuals."

In Australia, rates of obesity in both adults and children have increased over the last two decades. Due to the large burden that obesity places on individuals, families and the community, the Australian Government has set as one of its health priorities the halting and reversing of this trend. The prevention of obesity (including the associated risk factors of physical inactivity and poor diet) is a focus for health departments and agencies, both in Australia and overseas. As such, large investments in programs, initiatives and other activities that promote healthy lifestyles are being made. For example, the Australian National Preventive Health Agency includes obesity (alongside harmful alcohol consumption and smoking) as a key area for the development of risk reduction strategies[275].

Health reports highlight the rising rates of overweight and obesity in Australia as follows:

- Prevalence of overweight and obesity in adults aged 18 years and over has continued to rise to 63.4% in 2011-12 from 61.2% in 2007-08 and 56.3% in 1995. However the prevalence of overweight and obesity in children aged 5-17 has remained stable at 25.3% in 2011-12[405]
- The proportion of Australian men who are obese has almost doubled, and the proportion of obese women has increased from 8% to 20% over the past two decades [453].
- Overweight and obesity affects 25% of Australian children and adolescents[405]. Rates in children appear to be plateauing.
- In 2011-12, more men were overweight or obese than women (70.3% compared with 56.2%).
- Rates for both men and women have increased since 2007-08 (67.7% for men and 54.7% for women).
- Overweight and obesity varies with age, with 74.7% of adults aged 65-74 years being overweight or obese, compared with 38.4% of persons aged 18-24 years.
- On a global scale, the World Health Organisation has identified that sedentary lifestyles and high intake of energy-dense micronutrient-poor foods promote weight gain and obesity [466].

However the population appears to underestimate the extent of this health problem. Data from the Australian Bureau of Statistics in 2006 illustrates the discrepancy between self-reported weight versus actual weight, with just 32% of males and 38% of females considering themselves as overweight despite the actual calculated weight categories for the same group showing 62% of the same males and 45% of females were classified as overweight [467].

A consumer survey found that most Australians believed obesity was caused by an unhealthy diet, followed by a lack of exercise and self-discipline [468]. Furthermore, a survey of Australian shoppers showed two in three shoppers dieted to lose weight during 2006, however 87% believed that living a healthy lifestyle is more important than following a particular kind of diet [469].

However Australian health professionals have identified that although most overweight people understand what foods contribute to a healthy diet, many struggle to put this knowledge into practice [470].

In a 2006 Australian survey of beliefs and practices about egg intake, approximately 28% of respondents reported restricting their egg intake because they were either trying to lose weight, improve their diet or thought that eggs were fattening or too high in fat [471]. Positively, though a similar study conducted in 2012 found over the years there has been a softening in attitudes concerning a need to restrict egg intake for health or weight reasons[472] although 27% of respondents still reported fat content as a barrier to consumption ‘to some degree’. However a serve of eggs provides just 15% of a person’s daily fat requirements and 14% of daily saturated fat needs, while being a good source of high quality protein and providing at least 11 vitamins and minerals. Eggs are also relatively low in kilojoules, with a serve of eggs providing 7% of a person’s daily kilojoule requirements - around the same amount of kilojoules as 2 medium apples or 2 small slices of whole grain bread.

10.2 Weight management approaches

The conventional dietary approach to weight management (recommended by health authorities and most health professionals for the past 25 years) has been a high-carbohydrate, low-fat eating pattern [473]. However, whatever the macronutrient profile, successful dietary approaches to weight loss require a negative energy balance, equivalent to a daily reduction of 2000-4000 kilojoules [474]. High carbohydrate, low fat diets may not prevent weight gain or result in weight loss, as fat restriction alone does not necessarily result in lower energy intakes [474].

Research has shown that higher protein eating patterns may have benefits for some people including those with obesity, hyperinsulinaemia, type 2 diabetes, acne and polycystic ovarian syndrome [13,475-478].

However, any successful approach to the prevention of weight gain or weight loss requires kilojoule restriction tailored appropriately to a person’s level of energy expenditure [474]. This has resulted in the traditional recommendations being challenged as the ideal approach for all people.

Weight management also continues to be a major health priority for the food industry and added benefits are being increasingly explored for foods to help suppress hunger [479]. Addressing satiety, and ways to increase satiety with as few kilojoules as possible, is now a key focus for consumers and the food industry.

10.3 The Potential Role of Eggs in Weight Loss Diets

High protein, very low carbohydrate diets (35% energy from protein, 5% energy from carbohydrate)

The lure of rapid weight loss promised by these fad diets including the once-popular high protein, high fat Atkins diet makes them undoubtedly compelling, with survey results showing that more than one in five dieters reported using fad diets in 2001 [480]. Recent consumer research however indicates that fad diets are decreasing in popularity, with many consumers now focusing on sensible lifestyle choices rather than ‘diets’ [481].

Despite its popularity, long-term studies investigating the efficacy of the Atkins diet have been limited. Reviews of high protein, low carbohydrate diets, including the Atkins diet, that have been conducted to date show that these types of diets can be effective in reducing weight in the short to medium term [482]. However, after 12 months the amount of weight lost between Atkins style diets and conventional high carbohydrate low fat diets is equitable [483].

While high protein diets can result in weight loss, health professionals have raised significant concerns about the impact on other measures of health that may result from these diets. Prominent health organisations, such as the American Dietetics Association, the American Heart Association, the Dietitians Association of Australia and Diabetes Australia, have developed position statements advising against their long-term use, mainly due to their questionable safety. One of the key criticisms of these diets and one of the reasons they are not recommended as a long-term solution for managing overweight and obesity is their very high saturated fat levels [484]. As a result of criticism in this area, the Atkins diet was revised in 2002 to reduce the saturated fat levels.

Associations have been made in the literature, finding that women who reduce carbohydrate and increase protein, particularly if the protein is of animal origin, increase their overall risk of heart disease[485].
From a practical perspective, barriers to staying on low carbohydrate diets in the longer term have been identified. One study found that 40% of low carbohydrate dieters find the eating regime hard to adhere to for more than a few months at a time and 67% don't always maintain the recommended diet on a day by day basis [486].

Until the appropriate studies have been undertaken and these diets have been adequately evaluated, it would not be appropriate to endorse these diets or to promote the consumption of eggs within these dietary programs. Recent research has shown high intakes of animal protein, compared to plant protein, is associated with being overweight and obese [487] and an increased risk of heart disease[485]. Given this, it is important to promote egg consumption in the context of a well-balanced diet.

High carbohydrate, low fat eating patterns (55-60% energy from carbohydrate, fat intake less than 30% energy)
The conventional high carbohydrate, low fat eating pattern is still considered to be an effective strategy for weight loss [474], particularly if the carbohydrate-rich foods selected have a low glycemic index [474,488] or are wholegrain/high fibre. The contribution of protein to most high carbohydrate diets is 15-20% of total energy. Eggs fit well within this eating pattern with one serve of eggs providing around 10% of daily energy intake in a 6000kJ weight loss diet.

Moderate Protein, Moderate Carbohydrate Diets (30% energy from protein, 40% energy from carbohydrate)
Unlike the high protein-very low carbohydrate diets that prescribe severe carbohydrate restrictions and high saturated fat intakes, an alternative higher protein approach is one that is lower in fat (particularly saturated fat) and moderate in carbohydrate content (100-200g/day). These moderate protein, moderate carbohydrate diets have received more widespread acceptance from health professionals and respected research organisations. In Australia, the CSIRO released its moderate protein, moderate carbohydrate Total Wellbeing Diet in 2003.

A growing body of evidence, including a number of Australian clinical trials, has demonstrated moderately higher protein, lower carbohydrate kilojoule controlled diets can provide an effective weight loss strategy [18,475,489,490]. These diets may be particularly useful for individuals who have trouble with compliance on low fat, high carbohydrate diets due to hunger, or individuals with insulin resistance or diabetes [18-20,23,491].

Studies have also found that the style of eating recommended in a moderate protein, moderate carbohydrate eating plan, is easy to maintain, satisfying, and meets the needs of dieters [23,491-494] and when combined with physical activity, can reduce weight and body fat without lowering energy expenditure [495]. The results of the DioGenes study, published in 2011, found a high protein, low GI diet led to significant improvements in weight loss, glycaemic control and insulin sensitivity[496].Furthermore a systematic review and meta-analysis of studies published up until July 2011 found protein diets, with an average protein content of 27% of daily energy, resulted in modest improvements for weight loss, BMI, waist circumference, blood pressure and triglyceride levels compared with lower protein diets (5-23% daily energy)[29]. Similarly, another recent review and meta-analysis of research trials[497] compared energy-restricted high protein, low fat diets with standard protein, low fat diets on weight loss, body composition, resting energy expenditure, satiety and appetite and heart disease risk factors. The review included 24 trials with a total of 1063 individuals and an average length of 12 weeks. The researchers found that compared with a standard protein diet (average 17.5% of energy as protein), a high protein diet (on average 30.5% energy as protein) produced better reductions in body weight, fat mass and triglycerides. Changes in fasting plasma glucose, fasting insulin, blood pressure, and total, LDL, and HDL cholesterol were not different for the two diet types. Of the 5 studies that measured satiety, 3 found greater satiety on the high protein diet.

The other possible benefit of a higher protein weight loss diet is its effects on body composition. In one 12 month RCT, even though overall weight loss was similar between higher and lower protein diets, the higher protein diet was more effective at reducing the percentage body fat[498]

A recent study did find that a 6 week diet with 25% energy as protein increased cystatin C-based estimated glomerular filtration rate (eGFR) compared to diets with 15% energy as protein[499]. This signifies a negative impact on kidney function. Whether long term consumption of higher protein diets leads to kidney disease is still uncertain

The higher protein, moderate carbohydrate diets rely on regular serves of a wide range of high quality protein rich foods. Low saturated fat meals incorporating eggs would provide such protein and contribute to the variety of foods that are encouraged in this type of eating plan.

Weight Loss Studies Involving Eggs

Few studies have looked specifically at the effect of eggs on weight loss however new evidence supports the inclusion of eggs in an energy restricted diet with one study suggesting eggs may even enhance weight loss [332,334,500]. A study involving 152 overweight and obese adults found that those consuming two eggs for breakfast on at least 5 days of the week lost 65% more weight ($P < 0.05$) and 34% more from their waist circumference ($P < 0.06$) than those eating a bagel breakfast [500]. Similarly another study found that weight loss was achievable when two eggs were included in the daily menus of those following an energy-restricted diet with no adverse effects on blood cholesterol. This was despite an increase in dietary cholesterol intake [334]. Another group of researchers looked at the effect of eating 3 eggs per day as part of a carbohydrate-restricted (10-15% of energy from carbohydrate) weight loss diet in men. They found that the egg group induced similar changes in weight, waist circumference and LDL cholesterol to the group not eating eggs but that the egg group had a more favourable effect on HDL cholesterol and inflammatory markers, risk factors of heart disease [332,367].

A 2005 study also assessed the effect on satiety and subsequent short-term energy intake of a bagel based breakfast versus a breakfast containing eggs [416]. Twenty-eight overweight women aged 25-60 years were randomized to attend two test days two weeks apart.

Participants ate either an egg breakfast consisting of eggs, toast and reduced kilojoule fruit spread or a bagel breakfast consisting of a bagel, cream cheese and yoghurt.
The breakfasts varied in their macronutrient content but provided the same amount of kilojoules and were the same weight. Results showed a significant increase in satiety following consumption of the egg breakfast compared to the bagel breakfast. Energy (kilojoule) intake for the entire study period, from breakfast until noon the next day, was significantly lower by 1,759 kilojoules in those eating the egg breakfast (8,652.3 ± 2418.9 vs. 10,411.7 ± 3221.6, $p<0.001$). The greater satiety and lower total energy intake for at least 24hrs after the egg breakfast indicates eggs may play a useful role in weight loss treatments.

A 2010 study by Ratliff et al [501] has assessed the effect of consuming eggs for breakfast on satiety and energy intake throughout the day. Twenty-one men, aged 20-70 years old, consumed 2 test breakfasts, in a random order separated by 1 week. Both test breakfasts were approximately 1657 kJ of energy, however varied in macronutrient content. The egg-based breakfast (EGG) consisted of 3 scrambled eggs and 1.5 pieces of white toast. The bagel-based breakfast (BAGEL) consisted of 1 white bagel, 1/2 tablespoon of low-fat cream cheese, and 6 oz of low-fat yogurt. Results showed subjects consumed fewer kilojoules after the EGG breakfast compared with the BAGEL breakfast. In addition, subjects consumed fewer kilojoules in the 24-hour period after the EGG compared with the BAGEL breakfast. Based on the analysis, subjects were hungrier and less satisfied 3 hours after the BAGEL breakfast compared with the EGG breakfast. Participants had higher plasma glucose as well as an increased ghrelin and insulin area under the curve with the BAGEL breakfast. These findings suggest that consumption of eggs for breakfast results in less variation of plasma glucose and insulin, a suppressed ghrelin response, and reduced energy intake.

The difference between this study and the 2005 Vander Wal study is that this study looks at 24 hour intake in young men (as opposed to the 8 week study by Vander Wal) and does not look at the effects of BMI and weight loss directly, but rather looked at the effects of an EGG or BAGEL breakfast on calorie consumption throughout the day as well as effects on blood glucose levels, satiety and ghrelin concentrations (ghrelin is a hormone produced by the body that stimulates hunger). Overall, this study assessed more metabolic variables than the previous Vander Wal study and therefore helps demonstrate the mechanism as to why eggs may help people to lose weight.

A 2011 study[502] has assessed the effects of consuming eggs for lunch on satiety and subsequent energy intake. When subjects consumed the omelette their feelings of fullness where increased for 60 minutes after consumption compared to the jacket potato but no significant difference was found compared to the chicken sandwich. While the omelette made people feel fuller initially, subjects did not consume any less energy at the next meal (4 hours later). Increased feelings of fullness (satiety) after consumption of eggs at lunch appeared to be relatively short lived (up to 1hr), suggesting the beneficial effects may be in the form of reducing the urge to snack between meals rather than at the next meal (ie, dinner).

Further evidence of eggs increasing satiety comes from a 2012 breakfast study[503]. In this study healthy men consumed an egg breakfast, a croissant breakfast and a cereal breakfast. Participants showed increased satiety, less hunger and a lower desire to eat after the breakfast containing eggs relative to the cereal and croissant-based meals. The egg breakfast was also accompanied by a significantly lower energy intake relative to the croissant- and cereal-based breakfasts at the buffet lunch and evening meal.

How Dietary Proteins Regulate Food Intake and Body Weight

A review of dietary protein in the regulation of food intake has shown that protein makes a stronger contribution to satiety than carbohydrate and fat and also causes greater suppression of food consumption [504,505]. As a consequence, individuals may find it easier to comply with a higher protein diet due to reduced hunger. A protein-rich breakfast has been shown to increase feelings of fullness and reduce hunger in teenagers[505].

Higher protein meals have been shown to sustain satiety hormones (CCK and ghrelin) and suppress subsequent energy intake compared to higher carbohydrate meals[24]. Eggs, as a high protein food, have been shown to increase satiety related hormones following consumption. In one study, the effect of feeding 2 whole eggs, 2 egg whites, 2 egg yolks, or no eggs with a standard breakfast on gastric emptying, glycemic and hormonal responses were studied in 12 healthy young males [506]. Whole eggs and egg yolk induced a significant delay of gastric emptying, together with reduced blood glucose and insulin peaks (yolk only). Egg ingestion, whatever the part, increased gastric inhibitory peptide level in the blood. Cholecystokinin levels increased after whole egg or egg yolk ingestion potentially explaining the effect of eggs on satiety.

A number of studies have shown that higher protein diets may also preserve lean body mass (muscle) whilst reducing body fat. In a weight loss study of women consuming either 68g protein/day or 125g protein/day (15% or 28% of daily energy intake from protein respectively), changes in body weight were not significantly different between the 2 groups but the high protein group had a significantly higher loss of fat mass than the lower protein group [507]. In this study, the two diets were isoenergetic and provided similar amounts of fat (approximately 50g per day). In a similar weight loss study controlled for energy and fat intake, total lean mass was significantly better preserved in women undertaking a higher protein diet when compared to those following a standard protein diet [18]. None of these studies have assessed the independent effect of eggs on weight loss.

An Australian study [508] has shown that among overweight and obese people, choosing a low kilojoule eating plan based on higher protein meals improves the body's ability to burn fat, which may in turn help with weight loss. The eighteen study participants were provided with high protein meals that contained carbohydrate foods with either a high glycemic index (GI) or a low GI. All meals contained the same amount of kilojoules and were provided on separate occasions. After eating each meal, the amount of kilojoules subjects burnt up was measured. Consuming the higher-protein meal plans led to greater levels of fat burning than regular lower protein meals. These higher protein plans included an omelette for breakfast, and a beef and salad sandwich with a tub of low-fat yoghurt for lunch.

A 2004 study [509] suggests including high quality protein foods at breakfast to experience the metabolic advantages of a higher protein diet for weight loss. They also suggest the amino acid leucine is the key to higher protein diets because of its unique roles in regulation of muscle protein synthesis, insulin signaling and glucose re-cycling via alanine. They recommend protein levels above 1.5 grams per kilogram of body weight to get the benefits of higher protein intakes during weight loss.

A paper released by the British Nutrition Foundation in 2006 reviewed the evidence for dietary cholesterol, eggs and coronary heart disease risk. This paper also included a review of key studies promoting the satiating effect of eggs in assisting weight control. The researchers concluded that "moderate consumption of eggs (1-2 eggs per day) should be actively encouraged as part of an energy-restricted, weight-losing dietary regimen" [510].

A study [511] investigated the association between intakes of protein, arginine and lysine and changes in body composition in 8–10-year-old children. Results were collected over 6 years and found that among girls, high protein intakes may decrease body fat gain and increase fat free mass gain, depending on the available amounts and combinations of arginine and lysine.

Based on animal studies it is likely that the source of protein will also be a factor affecting short-term feeding responses. However, only limited investigations have been undertaken in humans. The potential role of egg protein (albumin) on food intake suppression remains to be determined.

One of the challenges for all dietary approaches aimed at weight loss is meeting recommended dietary intakes within a kilojoule-controlled diet. Eggs are a nutrient dense food, providing 581 kilojoules per serve, a high quality source of protein and 11 vitamins and minerals. While different weight loss diets are suitable for different people, eggs, as a nutrient dense food, are likely to play a useful role in most approaches.

Example communication messages:

- Eggs fit well within a moderately higher protein, lower carbohydrate eating plan for weight loss. This style of eating may have particular benefits for certain groups within the population.
- Eggs are high in good quality protein. Protein has been shown to contribute to greater feelings of satisfaction after eating and may therefore help people to stick to a weight loss diet for longer.
- Muscle loss may be minimised when on a weight reduction diet by including higher amounts of protein rich foods, such as eggs, as part of the eating plan.
- Protein diets containing an average of 27% energy as protein may assist in weight management and also have beneficial effects on blood pressure and triglyceride levels.

10.4 The Potential Role of Eggs in Other Diets

The Mediterranean diet is a collection of eating habits that are traditionally followed by the people of the Mediterranean region and which have been associated with excellent health [512]. Observational studies have shown that life expectancy for populations that habitually eat in this manner is among the highest in the world, and that these people also experience reduced incidence of coronary heart disease, cancers and other nutrition-related diseases [513]. A 2006 systematic review of experimental studies on the effects of Mediterranean eating patterns also showed favourable effects on blood lipoproteins, blood vessel functioning, insulin resistance, metabolic syndrome, antioxidant capacity, cardiovascular mortality and cancer incidence in obese people and those with a history of heart disease [513].

In this style of eating, an emphasis is placed on plant foods such as grains, vegetables, fruit, legumes, beans and nuts, as well as olive oil as the principal source of fat, moderate dairy consumption and a moderate red meat intake of only a few times per month. Fish, eggs and poultry are eaten weekly but also in small amounts. Approximately 0-4 eggs a week are consumed, which includes those used in cooking and baking.

Overall, research to date suggests there is no one dietary pattern to suit all individuals. Different diets are suitable for different people and eggs have a place in most if not all approaches.

Example key messages:

- Eggs fit well within a range of weight loss diets, providing significant amounts of vitamins, minerals and protein, while only contributing 581kJ per serve (2x60gram eggs).

10.5 Meal Patterns, Egg Intake and Weight Loss

Numerous studies have shown that different eating patterns are associated with body weight changes. For example, a review of studies investigating meal frequency and energy balance identified that the risk of obesity is lower among individuals who consume a greater number of meals per day [514]. Conversely, skipping breakfast has been associated with an increased risk of obesity [515] and frequent breakfast eating has been associated with lower BMI in adults [516-518]**.** There are also studies suggesting that individuals who skip breakfast have a greater daily energy intake [519,520].

Eating breakfast regularly and incorporating eggs as part of the meal may be an effective means towards promoting weight loss. A recent study compared the satiety value of an egg breakfast to an isocaloric bagel breakfast in a group of healthy, weight stable women. The egg breakfast induced greater satiety and a reduced energy intake at lunch by 29%. Furthermore, until midday on the day after the egg-breakfast, no compensatory increase in energy intake was reported [416]. Although this study did not investigate the mechanism whereby egg intake reduced satiety, an earlier study identified that egg consumption at breakfast significantly delayed gastric emptying and reduced blood glucose and insulin peaks when compared to a breakfast that contained no eggs [506]. A 2003 study showed after a 10-week dietary intervention, consumption of a high protein diet led to greater weight and body fat losses and a greater preservation of lean muscle mass compared to a high carbohydrate diet [507]. The high protein breakfast contained 30-33 grams of protein from egg, lean bacon, cheese, toast and milk. A recent study among 9 men consuming a normal amount of protein or a higher protein diet showed that a higher protein breakfast was more filling during an energy-restricted diet phase than other high protein meals throughout the day [494]. The initial and sustained feelings of fullness following protein consumption at breakfast suggests that the timing of protein intake differentially influences satiety during weight loss diets.

Further evidence of eggs increasing satiety comes from a 2012 breakfast study[503]. In this study healthy men consumed an egg breakfast, a croissant breakfast and a cereal breakfast. Participants showed increased satiety, less hunger and a lower desire to eat after the breakfast containing eggs relative to the cereal and croissant-based meals. The egg breakfast was also accompanied by a significantly lower energy intake relative to the croissant- and cereal-based breakfasts at the buffet lunch and evening meal.

However, not all breakfast studies that have included eggs are associated with lowered body weights. In a 2003 investigation of the types of food eaten at breakfast, eating cereal for breakfast was associated with a significantly lower BMI than eating meat and/or eggs for breakfast [421]. It is noted however that high fat foods such as bacon or sausages often accompany eggs at breakfast, and it may be these associated items and not the eggs themselves that may have influenced the results of this study.

In conclusion, research suggests that frequent meals and not skipping breakfast are associated with lower BMI. The satiating effects of a low-fat preparation of eggs at breakfast may help in a weight loss eating pattern.

Example communication messages:

- Eating eggs for breakfast as part of a low fat meal may assist in reducing food intake over the next 24 hours therefore helping weight management.
- Eating breakfast is associated with a lower body weight. Eggs are a healthy inclusion at breakfast with one serving (two eggs) providing around the same amount of kilojoules as 2 thin slices of toast.
- Eating protein rich foods such as eggs at breakfast may have benefits for weight loss.
- Eating eggs for breakfast can enhance weight loss when compared to eating a bagel based breakfast.
- When included as part of a low kilojoule or low carbohydrate diet, eggs do not increase blood cholesterol levels and in fact have been shown to lead to improvements in HDL levels.
- Consuming eggs for breakfast increases satiety and results in lower energy intake during the remainder of the day compared with a cereal or croissant breakfast.

11. Eggs and Food Allergies

This section provides an overview of egg allergy and summarises the recommendations regarding introduction of eggs to infants.

11.1 Prevalence and symptoms

In Australia, cow's milk, eggs and nuts cause most of the food allergies in infants and children [521]. Eighty per cent of food allergies in children are caused by these three allergens [522]. Australian data indicates that the prevalence of egg allergy in children at age 2 years is approximately 3.2% [521] which is double US estimates of 1.6% [523]. More recent data suggest that allergy to raw egg is as high as 8.9% in Australian children[524]. These figures confirm that egg allergy is frequent in a child population. Most egg allergy reactions occur in children between the ages of 6 and 15 months when egg is given for the first time. Most children (80.9%) of children with raw egg allergy can tolerate baked egg[524].

Clinical reactions to egg are predominantly IgE-mediated immediate reactions characterised by urticaria, angioedema, vomiting, diarrhoea and wheeze. Symptoms usually occur within 30 minutes or less of egg contact but may be delayed for 1–2 hours in a minority of cases [525]. Severe life-threatening events and fatal anaphylaxis to egg in children are less common than to peanut and milk [526].

A 2010 study found that many people who think they have food allergies really don't. The researchers reviewed more than 12,000 papers on food allergies published between January 1988 and September 2009 and found about eight per cent of children and less than five per cent of adults have allergic reactions to foods. Yet about 30 per cent believe they have food allergies [527].

11.2 Development of Egg tolerance

Fortunately, egg tolerance often develops between the ages of 2 and 4 years [528] resulting in many children being able to eat eggs as they get older. It has been estimated that approximately 85% of children outgrow food related allergies, especially those to cow's milk and egg [529], so prevalence of egg allergy in Australian adults may be as little as 0.5%. However recent research from the John's Hopkins Children's Centre suggests that in a highly atopic population, milk and egg allergies may be more persistent and harder to outgrow than previously thought. A review of 881 egg allergy sufferers showed the number of children who outgrow egg allergy increases with increasing age. Four percent outgrew this allergy by age 4, 37 percent by age 10, and 68 percent by age 16 [530]. A recent study has found children outgrow allergy to well-cooked egg approximately twice as fast as they outgrow allergy to uncooked egg[531]. The data supports the initiation of reintroduction of well-cooked egg from 2 to 3 years of age in children with previous mild reactions and no asthma.

A body of evidence is building which suggests that exposing children with egg allergy to small amounts of egg protein and/or baked egg may help build tolerance to all forms of egg faster. In one study of 55 children (5-11 years) 55% of those who had received small, frequent amounts of egg-white powder passed an oral food challenge after 10 months, compared to 0% of those who had received a placebo powder[532].

Another study[533] evaluated the efficacy and safety of a 6 month specific oral tolerance induction protocol in children with very severe hen egg allergy. In the study, 20 children (5-11 years old) were put in either a treatment group, who were exposed to a hen egg emulsion and then challenged after 6 months, or a control group. The control group were kept on an egg free diet for 6 months and then challenged as well. After 6 months, 9 out of 10 children in the treatment group achieved partial tolerance (tolerated at least 10ml of an egg emulsion but less than 40ml) and one was only able to tolerate 5ml. In the control group, 9 out of 10 tested positive to the egg challenge at less than 0.9ml of raw egg emulsion and one reacted to 1.8ml. All children in the treatment group had side effects but none were severe. These results showed 6 months of specific oral tolerance induction with raw hen egg emulsion led to partial tolerance in a significant percentage of children with severe egg allergy.

The use of baked egg, which is tolerated by a lot of children who are allergic to raw egg, has also been studied in relation to its ability to help build tolerance. In one study, children who could tolerate baked egg either chose to include it regularly in their diet or continue to totally avoid all forms of egg. Researchers found that those children who consumed the baked egg were 14.6 times more likely to develop regular egg tolerance during the 37.8months of study follow up compared to those who strictly avoided[534].

Another study using baked egg found no evidence that the rate of decline in egg skin prick test size differed between children who ingested baked egg frequently, regular ingestion or those who strictly avoided egg[535]. While not necessarily a positive finding, the researchers suggest that given dietary restrictions can adversely impact on the family, it is reasonable to consider including baked egg in the diet of egg allergic children.

While the research in this area is building, personal communication with Rob Loblay (Director, Allergy Unit, Royal Prince Alfred Hospital) suggests that these type of protocols are unlikely to be applied in the clinical setting until there is more definitive information on safety and efficacy. RPA do currently encourage children that do not react to a baked egg challenge to include baked egg in their diet regularly and after a few months introduce well-cooked (boiled or scrambled) egg with no runny bits (personal email communication, Rob Loblay 22.10.2012).

11.3 Major Egg Allergens

Egg white is considered to be the most frequent source of allergens and most children with an allergy react to the proteins in egg whites. Allergens have also been identified in the yolk, but reactions to egg yolk are less common [536]. Personal communication with an Australian infant feeding expert suggests egg yolk allergy is virtually unknown [537]. Even though a reaction to egg yolk is rare, the fact that reactions have been found suggests egg yolks may contain allergenic molecules that are different from the allergens in egg whites.

In an allergy study on egg white proteins it was shown that conalbumin (ovotransferrin) and ovomucoid were the most frequent allergens, with frequencies of reactivity being 53% and 38% respectively in people with an egg allergy [536]. Other egg white allergens ovalbumin and lysozyme had frequencies of reactivity of 32% and 15% respectively [536]. In egg yolks, the protein alpha-livetin is thought to act as an allergen [536]. Alpha-livetin has been implicated in the sensitisation to egg proteins via the inhalation route [538]. However, allergic disease has been reported due to inhalation of both egg white and egg yolk aerosols [538-540].

Reactions can occur to both cooked and raw egg whites [541]. Heating and gastric pH reduces the allergenicity of several egg white proteins [542], which provides an explanation for children who react to raw but not cooked egg and egg products [543]. A 2013 study confirmed that some cooking methods (in this study traditional Chinese cooking methods) appear to weaken the allergenicity of eggs[544].

The ovomucoid proteins in egg whites have been shown to have reduced allergic sensitisation once they have been heated. Therefore, a negative allergic response to cooked eggs does not guarantee that an individual with an egg allergy has achieved complete egg tolerance. Anaphylactic reactions to raw eggs have been reported in individuals after a negative challenge with cooked eggs [541]. In addition, the proteins in hen's eggs are similar to those of other birds, so individuals with significant hen's egg allergies should refrain from consumption of all eggs. Only a single study to date has indicated that some individuals may be allergic to eggs from duck and goose but remain tolerant to hen's eggs [545].

Recent evidence suggests it might be possible to reduce the time it takes children to grow out of their allergy. More than 95% of egg-allergic preschool children who were exposed to small amounts of cooked egg in cake each day for six months tolerated egg when challenged. It is however unclear if these children would have naturally grown out of their allergy during the study, indicating further research is required in this area [546]

CSIRO have recently announced a new project in which they plan to produce allergy free eggs. They plan to take ordinary chickens and "turn off"the allergens inside it. This will produce a chicken that lays allergy free eggs. The project aims to have the allergy free eggs on the supermarket shelves within 5 to 10 years.

11.4 Prevention of Egg Allergy in At-Risk Children

Both genetic and environmental factors are likely to be responsible for the development of an allergy. At present, family history of all immediate family with allergies or asthma is the only viable method to classify children as 'at risk' as routine screening by genetic or biochemical means is not yet available. A family history would include all immediate family, including parents and children with an allergy or with a history of an allergy. Recently, a study as part of the Australian HealthNuts allergy study of 5276 infants found that children with older siblings and those with a pet dog at home were less likely to develop egg allergy by 1 year of age[547]. Caesarean section delivery, antibiotic use in infancy, childcare attendance and maternal age were not associated with egg allergy. History of allergic disease in an immediate family member and having parents born in East Asia were strong risk factors for infantile egg allergy.

It has also been recently shown that children with atopic dermatitis are at six times higher risk of sensitisation to egg than a child without atopic dermatitis before the first known ingestion[548].

IgE, the immunoglobulin class responsible for allergic antibodies, is present in both allergic and non-allergic children. However, allergic children are more likely to produce more IgE allergen-specific antibodies than normal children. As food proteins have been identified as important allergens in early childhood, a hypoallergenic diet may help prevent the development of a specific food allergy in high-risk children [549]. Thus, avoidance of egg proteins in the diet of an at-risk infant may prevent an egg protein allergy.

Depending on the type of allergy and its severity, allergen avoidance may begin as early as pregnancy and be followed for up to several years through the child's infancy. For at-risk individuals, the evidence for egg avoidance through these phases will be reviewed.

Avoidance of Allergens During Pregnancy

The recognition of allergens by cord blood cells indicates that allergen priming occurs prenatally. However, studies examining maternal elimination diets of highly allergenic foods, including eggs, during late pregnancy have not been shown to provide significant benefits [550,551]. The Australian Society of Clinical Immunology and Allergy (ASCIA) does not recommend restricting the mother's diet during pregnancy in order to eliminate 'allergenic foods' (including peanut, egg, fish, soy and cows milk) as research does not support this as a strategy for reducing the development of allergenic diseases [552].

Eggs can be included in the diet of pregnant women as long as they are tolerated by the mother.

Avoidance of Allergens During Breastfeeding and Infancy

There is conflicting evidence on the effects of maternal avoidance of allergenic foods during lactation and exclusive breastfeeding for 6 months or longer to reduce the incidence of allergic disease in high risk infants [552]. ASCIA does not recommend maternal dietary restrictions during breastfeeding as a preventative measure, and suggests breastfeeding for at least the first 4-6 months in children at risk of allergic disease [552]. It has been suggested that for high-risk infants, eggs should be avoided at least for the first 12 months of life [528]. However ASCIA recognise there is no evidence that dietary restrictions after 6 months of age have any additional benefits [552]. This conclusion is also supported by the European Society for Paediatric Gastroenterology, Hepatology and Nutrition (ESPGHAN), whose 2008 Complementary Feeding position paper concludes "there is no convincing scientific evidence that avoidance or delayed introduction of potentially allergenic foods, such as eggs, reduces allergies, either in infants considered at increased risk for the development of allergy or in those not considered to be at increased risk" [553]. Furthermore, some studies have also shown that delayed introduction of solids can increase the risk of developing atopic disease [553]. Another recent review on infants with atopic eczema suggests there may be some reduction in symptoms in those with suspected egg allergy (who have positive specific IgE to eggs in their blood) by adopting an egg-free diet [554].

Introduction of Eggs to Non-allergic Children

In Australia, dietary guidelines recommend the introduction of solid foods at the age of approximately 6 months, beginning with the introduction of iron-enriched infant cereals. Vegetables, fruits, meats, poultry and fish are then added gradually [11]. Egg yolks are suggested as an example of a food that infants of age 8-12 months can consume [11]. There are no recommendations for the introduction of egg whites to the diet but it may be inferred that they be introduced after the age of 12 months. The dietary guidelines emphasise that introduced foods should be of high nutrient density and that first foods introduced should be soft and smooth textured. Eggs are highly appropriate for consumption at this stage of development being protein-rich, energy dense and of smooth texture.

Of note is that Australian research has shown that up to 4 egg yolks a week can be introduced in a balanced diet for infants aged between 6-12 months without raising plasma cholesterol and markers of allergy [113].

In summary, the following recommendations for eggs and allergy can be made:

Infants with a family history of allergic diseases

- During pregnancy and lactation, restricting the mother's egg intake is not necessary.
- Breastfeeding is recommended for at least the first 4-6 months.

Infants without a family history of allergic diseases

- The Australian Dietary Guidelines for Children and Adolescents include the suggestion that egg yolk be introduced from 8 months of age [11]. This is a suggestion only with research showing egg yolk can be well tolerated by infants from 6 months of age [113].
- There are no specific guidelines for the introduction of egg white however it is generally recommended from 9-12 months of age.

11.5 Clinical Threshold for Eggs

The amount of food required to induce a clinical reaction is very important, as fatal accidents from trace amounts of food have been reported. At present, the DBPCFC is considered to be the most suitable way of establishing or ruling out an adverse reaction to a food, however a number of other testing procedures are often performed.

A 2004 Position Paper from the European Academy of Allergology and Clinical Immunology propose that the starting dose for an egg challenge should be 1mg [555]. This amount represents a starting dose that is expected to be well below the threshold so that determination of the actual sensitivity in the individual can be subsequently determined. In a 2003 study examining thresholds of clinical reactivity to egg, it was identified that 16% of individuals with egg allergies reacted to 65mg of egg as a solid food (equivalent to 6.5mg of egg protein). It was found that 0.8% of individuals with egg allergies reacted to 10mg or less of solid food and that the lowest reactive threshold was observed at less than 2mg of egg [556]. The results from this study establish that in order to guarantee a safety of 99% for individuals allergic to eggs, a sensitivity limit of 10parts per million is required (on the basis of consumption of 100g of food). This information is important for food manufacturers making egg free claims on their products.

11.6 Eggs and Asthma

Diet has generally been considered to play only a minor role in the management of asthma, however recent studies are beginning to present a different perspective. In a study of children diagnosed with asthma, 72% of individuals were found to be sensitive to only one food allergen. The most common food allergens identified were milk and egg white [557]. The authors from this study suggest that the allergic asthmatic response was most likely to be related to food rather than aeroallergens or fungal allergens.

The use of exclusion diets in the management of asthma remains controversial due to concerns of subsequent nutritional adequacies and doubt of their overall effectiveness. However, in a 2004 study of children clinically diagnosed with asthma, it was shown that even over a short time period of 8 weeks, an egg- and milk-free diet significantly reduced atopic symptoms of asthma and improved lung function [558].

A review of therapeutic measures for the prevention of asthma has recommended that the consumption of eggs should be delayed in infants identified as high-risk until the age of 2 years [559]. However in contrast, a follow-up study of 642 infants identified that the late introduction of egg was not protective against the development of asthma in infants [560].

In summary, evidence is beginning to emerge that, in some individuals, food allergens may play a role in the development of allergic diseases such as asthma. Studies to date indicate that eggs may be one of the more common foods to which people with asthma are sensitive. However, further research is warranted before any conclusions can be drawn.

Example communication messages:

- Egg allergy is one of the most common allergies in children and may be as high as 9%
- Approximately 85% of children will grow out of their egg allergy.
- Parents with egg allergy should be particularly careful to avoid the presence of eggs around their infants in order to minimize sensitization via the inhalation route.
- People with an allergy to egg should avoid all types of eggs, including duck, goose and quail.
- Healthy infants with no family history of egg allergy may eat egg yolk from 6-8 months of age.

12. Eggs and Cancer

This section summarizes the current evidence relating dietary intake of eggs and cancer.

12.1 Breast cancer

A 2003 study [561] prospectively examined the relationship between meat, fish and egg intake on breast cancer risk in 88,647 women enrolled in the Nurses Health study. Results found a weak positive association of breast cancer risk with egg intake for an intake of approximately 2 eggs per day.

A pooled analysis of cohort studies [562] suggested a J-shaped association for egg consumption where, compared to women who did not eat eggs, breast cancer risk was slightly decreased among women who consumed <2 eggs per week but slightly increased among women who consumed ≥1 egg per day. This inconsistent relationship between egg consumption and risk of breast cancer warrants further investigation

In contrast, a study of more than 3,000 adult women [136] found that choline, an essential nutrient found in eggs, may be protective against breast cancer. Results found the risk of developing breast cancer was 24 percent lower among women with the highest intake of choline compared to women with the lowest intake. Women with the highest intake of choline consumed a daily average of 455 mg of choline or more, obtaining most of this from coffee, eggs and skim milk. Women with the lowest intake consumed a daily average of 196 milligrams or less. One serve of eggs contains around 420mg of choline.

Similarly, a study published in 2003 by researchers at Harvard University [563] found that women who reported higher consumption of eggs, vegetable fat and fiber during adolescence had a smaller risk of developing breast cancer as adults. Specifically, eating one egg per day was associated with an 18 percent reduced risk of breast cancer.

Another study of Chinese women [564]showed that those who consumed the most fruit, vegetables and eggs were significantly less likely to have breast cancer. For those that reported eating at least six eggs per week, the risk of developing breast cancer was 44 percent lower than for those who ate two or less eggs per week.

However, looking at data from the European Prospective Investigation into Cancer (EPIC) in 319,826 women conducted over 8.8 years, there was found to be no consistent association between the risk for breast cancer and dietary intake of eggs in any of the groups studied.[565]

Overall, a comprehensive report released by The 2007 World Cancer Research Fund on cancer prevention [566] based on a review of 7,000 studies looked at all aspects of diet, physical activity, weight management and breast cancer and concluded that “observational epidemiologic studies do not consistently implicate consumption of any animal food (such as eggs) in breast cancer risk”.Results suggest that egg consumption has not been consistently identified as a risk factor for breast cancer, and further studies are warranted.

12.2 Ovarian Cancer

The relationship between diet and the risk of developing ovarian cancer is unclear. This section aims to explore the relationship between diet (particularly eggs) and risk of ovarian cancer.
A case-control study published in 2002 [567] aimed to determine whether eggs were associated with ovarian cancer risk. Women were classified into four groups, based on their reported frequency of whole egg consumption: (a) <1 per fortnight; (b) from 1 per fortnight to <1 per week; (c) 1–2 per week; and (d) >2 per week. A strong and significant dose-response relationship between cholesterol from eggs and risk of ovarian cancer was found. However, there was no such positive association with cholesterol from non-egg sources. The lack of an association between non-egg cholesterol and ovarian cancer implies that the observed association between egg consumption and ovarian cancer risk is not due to the cholesterol in eggs. The data of Risch et al.[568] support this contention.

In a pooled analysis of 12 cohort studies [569] including 553 127 subjects from the Canadian National Breast Screening Study, Netherlands Cohort Study, the Nurses' Health Study, Nurses Health Study II, Adventist Health Study, Swedish Mammography Cohort, Iowa Women's Health Study, New York State Cohort study, New York University Women's Health Study, Breast Cancer Detection Demonstration Program, Cancer Prevention Study Nutrition Cohort and Women's health study, aimed to investigate the associations between intakes of fat, cholesterol and eggs and risk of ovarian cancer Results found that among the women, egg consumption was not significantly associated with ovarian cancer risk

In support of this finding, another prospective cohort study [570]found that in at 14.7 year study of 66,651 women from the Swedish Mammography cohort, no significant association was observed between consumption of red meat, fish, or egg and incidence of total epithelial ovarian cancer

At present, the evidence is limited and the intake of eggs it not consistently linked to risk for ovarian cancer.

12.3 Prostate cancer

A 2010 study [571] followed 1294 men with prostate cancer, without recurrence or progression for an average of 2 years. Results found that intakes of processed and unprocessed red meat, fish, total poultry, and skinless poultry were not associated with prostate cancer recurrence or progression. However greater consumption of eggs (5.5 eggs per week) resulted in twice the risk for prostate cancer progression compared with men who ate less than one egg per week.

In support of this finding, a case-control study [572] of 11 cancer sites in Uruguay between 1996 and 2004 also found an association between higher intake of eggs (>3.5 eggs/week) and increased risk of prostate cancer.

Conversely a review of 37 prospective cohort and four intervention studies published between 1966 and September 2003 [573] on potential dietary risk factors for prostate cancer found that overall consumption of meat, eggs, vegetables, fruit, coffee, tea, carotenoids and vitamins A, C and D was not consistently related to prostate cancer risk.

An ongoing prospective cohort study of male health professionals has found men who consumed 2.5 or more eggs per week had an 81% increased risk of lethal prostate cancer compared to men who consumed less than 0.5 eggs per week. Researchers, however, found no association between egg consumption post-diagnosis and risk of lethal prostate cancer.

Men who consumed more eggs had a higher average BMI, engaged in less vigorous activity, were more likely to be current smokers, have a history of type 2 diabetes, and a family history of prostate cancer and tended to eat less poultry and fish and more dairy compared to men who consumed the least number of eggs. Three previous studies examining egg consumption in relation to prostate cancer have found mixed results, therefore given the limited data available additional research on egg consumption and risk of lethal prostate cancer is warranted[574].

The most recent study to be published in this space was a meta-analysis of studies published up until July 2012[575]. When the studies were pooled together no type of study (case-control or cohort) showed any association of prostate cancer incidence with egg consumption. No association was observed between egg consumption and prostate cancer-specific mortality either. This analysis suggests there is no evidence that egg consumption has a significant influence on prostate cancer incidence and mortality, however, researchers called for larger studies to be conducted.

12.4 Colon and colorectal cancer

A systematic review published in 2006 [576] looked at 15 studies on dietary intake and colorectal cancer. Five studies reported a positive association between egg consumption and colon cancer risk, but three other studies failed to confirm those results. Overall, the available data suggest that high (almost daily) consumption of eggs may increase colorectal cancer risk.

A case-control study of 11 cancer sites in Uruguay [572] between 1996 and 2004 also found an association between higher intake of eggs (>3.5 eggs/week) and increased risk of colon cancer.

The World Cancer Research Fund in 2007 [566] undertook a systematic review on the association between eggs and colon cancer. There were 7 publications including six cohort studies that reported on egg consumption and risk for colorectal cancer [577-583].

The first study by Phillips et al (1975) [577] in the Seventh-Day Adventist population, found no association between consumption of eggs and risk of colon cancer. However in another study [578] with the same cohort, the use of eggs showed a positive dose-response relationship with fatal colon cancer in both males and females; however, statistical significance was attained only when both sexes were combined This positive association was strongest among older males and younger females.

A study by Jarvinen et al [579] analyzed a Finnish cohort of 9,959 men and women without diagnosed cancer at baseline (1966-1972). During the followup a total of 109 new colorectal cancer cases (63 in the colon) were identified. Results showed a non significant association between between consumption of meat and eggs and colorectal cancer risk.

Another study [580] showed no relationship between egg intake and colon cancer in a model adjusting for age, sex, BMI, physical activity, parental history of colon cancer, current smoking, past smoking, alcohol consumption, and aspirin use.

Hsing et al (1998) [581] investigated the association between colorectal and colon cancer death in a male cohort. Participants were grouped into quartiles with consumption of eggs <0.4 times/month as a reference group, and a consumption of >21times/month as the highest intake category. Compared to the reference group, conpeople who consumed eggs >21 times/month had a non-significant increased risk for both colon and colorectal cancer death

A similar pattern was seen in the Japan, Hokkaido cohort study initiated in 1984-1985 and continued until 2002 [582]**.** The study assessed links between four leading cancers (including colorectal cancer) and common Japanese dietary factors, which included 3,158 subjects for analyses. The results found that increased egg consumption showed a statistically non-significant increased risk for colorectal mortality in men and women

Results from the Oxford vegetarian study [583] with a mean of 17 years of follow-up, found 95 incident cases of colorectal cancer occurred (39 in vegetarians). Egg consumption was divided into three levels and a consumption of <1 time/week was regarded as the reference group, while a consumption of >=6 times per week was the uppermost category. Those with the highest consumption level showed an increased but statistically non-significant risk for colorectal cancer.

In conclusion, the WCRF stated no statistically significant association between egg consumption and the risk of colorectal polyps in a meta-analysis, which included 7 publications in six cohort studies.

12.5 Bladder Cancer

A 2012 meta-analysis identified 4 cohort and 9 case-control studies of egg intake and risk of bladder cancer[584]. Overall, the analysis found no significant association between egg consumption and bladder cancer. When assessing different geographical regions, the researchers found egg consumption was associated with a 28% reduced risk in Japanese.

13. Government Recommendations Regarding Egg Intake

This section provides an overview of national and international government recommendations regarding the role of eggs in a healthy eating pattern and in managing blood cholesterol levels.

13.1 General Healthy Eating Guidelines

In Australia, dietary guidelines for children, adolescents and adults recommend that individuals 'Enjoy a Wide Variety of Nutritious Foods' [11,585]. Lean meat, fish, poultry and/or alternatives are listed as preferred protein sources of foods, and eggs are included as an alternative. There are no recommendations specifying or restricting the amount of eggs that should be consumed.

Based upon a food group model set to achieve the Recommended Dietary Intakes (RDIs), the Australian Guide to Healthy Eating (AGHE) [586] uses a 'plate' format rather than the traditional food pyramid or five food groups that had been used previously in Australia. The AGHE encourages consumption of a variety of foods from each of the five major food groups daily and in proportions that are consistent with the Dietary Guidelines for Australians. Eggs are included in the 'meat, fish, poultry, eggs, nuts, legumes' group of the AGHE and 2 small eggs are represented as a single serve. There are no specific recommendations regarding the frequency of egg intake within this guide. The new draft AGHE, released for comment in December 2011, specifies 2 large eggs (120g) as a single serve.

The US Department of Agriculture's (USDA) Dietary Guidelines for Americans recommend individuals to 'Build a Healthy Base' and to 'Choose Sensibly' [587]. The food groups are depicted in a pyramid formation and eggs are included in the 'meat' section of this pyramid. Although the Guidelines provide examples of major food sources containing saturated and trans fats to avoid, no reference is made to major food sources of cholesterol.

No specific recommendations are made for egg intake within these guidelines, however the guidelines do advise to "Use egg yolks and whole eggs in moderation" and to "Use egg whites and egg substitutes freely when cooking since they contain no cholesterol and little or no fat".

The 2010 Dietary Guidelines for Americans includes eggs in the list of nutrient-dense foods and beverages to be emphasised in the diet[587]. Choose a variety of protein foods including eggs. The USDA food patterns contained in the dietary guidelines include the following food groups: vegetables, fruits, grains, dairy products and protein foods. Eggs are included in the protein foods group. The guidelines recommend the consumption of 0.4oz. eggs per day in an average food pattern and 0.6oz. per day in a lacto-ovo food pattern.The guidelines mention eggs as a source of dietary cholesterol and there is a suggestion in the document to limit intake of egg yolk to 4 per week.

Canada's Food Guide to Healthy Eating was updated in 2007 [588]. Four major food groups, being grain products, vegetables and fruit, milk and alternatives, and meats and alternatives, as well as a fifth group for 'oils and fats', are displayed in a rainbow graphic in the guide. Two eggs is designated as a serving and no specific restrictions are placed on egg consumption.

The UK Food Standards Agency's Balance of Good Health is a pictorial guide to a healthy diet [589]. The Balance of Good Health is a plate model outlining foods from the major food groups however no specific amounts of foods from the five food groups are recommended and there are no guidelines on portion sizes other than for fruit and vegetables. While eggs are included in the meat, fish and alternatives group, there are no recommendations on how often and how many eggs to consume as part of a healthy diet. The guidelines relevant to this food group recommend eating moderate amounts from this group and choosing lower fat versions.

In summary, eggs are represented as an alternative to meat, poultry and fish and represent an occasional protein alternative in Australian and international general healthy eating guidelines. No dietary guidelines presented here impose specific restrictions on egg consumption in the context of a healthy eating plan.

13.2 Guidelines Relating to Cholesterol and Egg Consumption

The (now rescinded) National Heart Foundation of Australia's (NHF) 2001 Lipid Management Guidelines set no specific recommendations for restricting egg intake in relation to dietary cholesterol intake [319]. The guidelines did state to "limit cholesterol-rich foods such as egg yolk and offal". The (also now rescinded) 2005 updated Position Statement on Lipid Management [590] made no reference to dietary cholesterol, instead stating that dietary advice for lipid management to reduce CVD risk should be based on recommendations to follow a low saturated fat eating plan incorporating moderate amounts of polyunsaturated and monounsaturated fats and oils, marine omega-3s via two to three fish meals per week and at least 2g of plant omega-3s (Alpha Linolenic Acid) per day, and a wide variety of fruits, vegetables and wholegrain cereal products. These two documents have now been replaced by the 'Absolute risk management guidelines' and 'Reducing risk in heart disease reports', both dated 2012 (discussed below).

The National Heart Foundation's, *Guidelines for the management of absolute cardiovascular disease risk report,* released in May 2012 states (in the section of treatment under 'Lifestyle' that General lifestyle advice to those at higher absolute risk of CVD should include the following advice on diet: "Consume a varied diet rich in vegetables, fruits, wholegrain cereals, lean meat, poultry, fish, **eggs**, nuts and seeds, legumes and beans, and low-fat dairy products". Other advice includes limiting foods containing saturated and trans fat but there is no mention of a recommendation to limit dietary cholesterol intake[591].

In the 2012 *Reducing risk in heart disease (An expert guide to clinical practice for secondary prevention of coronary heart disease[592])* report, as part of the nutrition advice section health professionals are advised to:

- Advise patients to consume > 2 g ALA per day by including canola- or soybean-based oils and margarinespreads, seeds (especially linseeds), nuts (particularly walnuts), legumes (including soybeans), **eggs** and green leafy vegetables.

Dietary guidelines

The NHF 2009 Position Statement on Dietary Fat [31] states there is good evidence that an increase in the consumption of saturated fatty acids is associated with an increase in risk of CHD, and moderate evidence that dietary cholesterol increases total cholesterol and LDL-C but substantially less so than saturated and trans fatty acids. They recommended that within a low saturated fat diet, individuals may consume up to six eggs per week without adversely affecting CVD outcomes

In 2004, the National Heart Foundation of Australia announced that whole fresh eggs were eligible to carry the Tick. The Heart Foundation recognise eggs as an affordable, nutritious and readily available food and that by carrying the Tick, this assisted in communicating to consumers that eggs are a nutritious food and a healthy inclusion in a balanced diet. In making the announcement in Australia in 2005, the Heart Foundation recommended people with heart health concerns seek advice from their doctor or an Accredited Practising Dietitian regarding their intake of egg yolks, however stated that this advice did not apply to the healthy population. In Canada, eggs are also eligible to carry the Heart and Stroke Foundation of Canada (HSFC)'s Heart Check™ symbol.

Other Australian regulatory bodies such as the Dietitians Association of Australia and Diabetes Australia do not have a position statement regarding egg intake with respect to cholesterol consumption.

The American Heart Association's (AHA) most recent scientific statement 593 highlights lifestyle changes in addition to dietary factors that should be considered for reducing cardiovascular disease risk. The AHA Committee recommended a reduction in saturated fat to less than seven percent of total calories and trans fat to less than one percent, lower than the recommendations from earlier guidelines 349,594. However the 2006 revision 593 retained the earlier recommendation that dietary cholesterol intake should be limited to less than 300mg per day for the general population. No limitation on egg or egg yolk intake was recommended. The Diet and Lifestyle recommendations listed on the current AHA website (updated Feb 2013) also retain the advice "Cut back on foods high in dietary cholesterol. Aim to eat less than 300 milligrams of cholesterol each day". Furthermore, the website currently contains a number of articles with healthy eating tips including recommendations to replace egg yolks with egg whites or cholesterol free egg substitutes. They continue to recommend people with high LDL blood cholesterol levels or who are taking a blood cholesterol-lowering medication should eat less than 200 mg of cholesterol per day.

Another US advisory body, the National Education Program Expert Panel on Detection, Evaluation and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) published in 2002 recommends <200mg dietary cholesterol a day for people with existing elevated blood cholesterol levels. Less than or equal to 2 egg yolks a week are recommended and egg yolks and whole eggs are listed in the 'choose less often' category of the healthy lifestyle recommendations for people with high blood cholesterol levels. Egg whites or egg substitutes are freely recommended [595]. Interestingly, the consumer booklet designed by the National Heart, Lung, and Blood Institute to help individuals translate the ATP III recommendations into practice [596] states that "saturated fat raises your blood cholesterol more than anything else in your diet."

Health Canada's Dietary Reference Intakes for Energy, Carbohydrate, Fibre, Fat, Fatty Acids, Cholesterol, Protein and Amino Acids (Macronutrients), released in 2002, set no tolerable upper limit for dietary cholesterol intake, stating that any incremental increase in cholesterol increases CHD risk [597]. No references to egg intake are made. No references to egg intake in relation to cholesterol intake were made in Canada's Food Guide to Healthy Eating [598].

The Heart and Stroke Foundation of Canada advise the following in relation to reducing blood cholesterol levels "One long-standing myth about high blood cholesterol is that it is caused by eating foods containing cholesterol. It's not so – research shows that it is the fat in food, particularly the saturated and trans fat, and not the cholesterol in food that raises blood cholesterol the most. Although the majority of people are not adversely affected by food cholesterol, a small percentage of people, particularly those with a family history of high blood cholesterol, are very sensitive to it and must limit it." [599]

The Heart and Stroke Foundation of Canada (HSFC) [600] acknowledges that dietary cholesterol can raise blood cholesterol, however recognising that this effect is "not nearly as much as high fat foods, especially those high in saturated and trans fat". HSFC recommends that individuals consume dietary cholesterol in moderation. Eggs are recognized as a nutritious food and "healthy people can eat eggs in moderation without any harmful effects on blood cholesterol levels". No limit on dietary cholesterol or eggs is included among the Foundation's '10 ways to get your cholesterol in check'. However, for individuals whose cholesterol remains elevated, HSFC recommends they limit egg consumption to two per week.

The British Nutrition Foundation's Healthy Eating fact sheet on eggs highlights that although eggs contain cholesterol, it is thought that healthy adults can consume an egg a day without adversely affecting blood cholesterol [601].

The British Nutrition Foundation authored a paper published in the BNF Nutrition Bulletin in 2006, reviewing dietary cholesterol, eggs and coronary heart disease risk. This review concluded that "moderate consumption of eggs (1-2 eggs per day) should be actively encouraged as part of an energy-restricted, weight-losing dietary regimen" [510].

The British Heart Foundation's latest statement with respect to eggs is as follows: "For most people there is currently no limit on the number of eggs that you can eat in a week. However, because the recommendation has changed over the years, it's often a common source of confusion...for most people, the amount of saturated fat they eat has much more of an impact on their cholesterol than eating foods that contain cholesterol, like eggs and shellfish. So unless you have been advised otherwise by your doctor or dietician, if you like eggs, they can be included as part of a balanced and varied diet. (http://www.bhf.org.uk/heart-health/conditions/high-cholesterol.aspx; accessed Feb 2013). For those with Familial hypercholesterolaemia, the British Heart Foundation, suggests no more than three or four eggs a week[602]
Internationally, the World Health Organization's (WHO) report on Diet, Nutrition and the Prevention of Chronic Diseases made the following recommendations for egg consumption in relation to dietary cholesterol intake and prevention of CV disease [466]. It stated that "egg yolk is particularly rich in cholesterol but unlike dairy products and meat does not provide saturated fatty acids". The recommendations then state, "If intake of dairy fat and meat are controlled, there is no need to severely restrict egg yolk intake, although some limitation remains prudent".

In conclusion, the majority of national and international regulatory bodies do not specifically impose a restriction on the intake of eggs with respect to dietary cholesterol intake (table 10). However, eggs are recognised as a significant source of dietary cholesterol and moderate or 'prudent' consumption is advised.

Table 10: Summary of Recommendations Regarding Egg/Dietary Cholesterol Intake and Heart Health

Country	Recommendation regarding egg intake
National Heart Foundation of Australia – - general population and those with elevated blood cholesterol levels	Within a low saturated fat diet, individuals may consume up to six eggs per week without adversely affecting CVD outcomes.
American Heart Association - general population - those with high cholesterol	<300mg dietary cholesterol per day no restriction on eggs < 200mg cholesterol per day
National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation and Treatment of High Blood Cholesterol in Adults – NHLBI, NIH -U.S. – recommendations for people with elevated blood cholesterol levels	<200mg dietary cholesterol a day - less than or equal to 2 egg yolks a week including those in baked goods and cooked and processed foods
Heart and Stroke Foundation of Canada – - general population	- no restriction on eggs but acknowledges dietary cholesterol can raise blood cholesterol level but not nearly as much as dietary fat - focus is on saturated and trans fat
British Heart Foundation - recommendations for people with Familial Hypercholesterolemia	- three to four eggs a week (FH) - no restriction on eggs for general population or those with moderately high cholesterol.
World Health Organization – general population	- if intake of dairy fat and meat are controlled, there is no need to severely restrict egg yolk intake, although some limitation remains prudent
USDA-HHS Dietary Guidelines/USDA - general population	< 300mg cholesterol per day Suggestion of up to 4 egg yolks per week
MyPyramid - general population	No specific restriction on eggs but caution that egg yolks high in cholesterol
Joint Task Force of European and Other Societies - patient population - high risk patients	< 300mg cholesterol per day - specialist dietary advice but no specific restriction on eggs
Working Group on Hypercholesterolemia and Other Dyslipidemias (Health Canada) - population with high risk for CVD	- no restriction on eggs or cholesterol - focus is on saturated and trans fat (< 7% of total energy)

14. Appendices

Appendix 14.1 Recommended dietary intakes for children under 9 years [2]

	Per serve (2 medium eggs)	Infants				Young Children			
	104g	**0-6 months**	**%AI**	**7-12 months**	**%AI**	**1-3 yrs**	**%RDI**	**4-8yrs**	**%RDI**
Vitamin A (µg retinol equiv)	239	250	96%	430	56%	300	80%	400	60%
Thiamin (mg)	0.12	0.2	60%	0.3	40%	0.5	24%	0.6	20%
Riboflavin (mg)	0.5	0.3	167%	0.4	125%	0.5	100%	0.6	83%
Niacin (mg niacin equiv)	0	2	0%	4	0%	6	0%	8	0%
Vitamin B6 (mg)	0.05	0.1	50%	0.3	17%	0.5	10%	0.6	8%
Total folate (µg)	97	65	149%	80	121%	150	65%	200	49%
Vitamin B12 (µg)	0.8	0.4	200%	0.5	160%	0.9	89%	1.2	67%
Vitamin C (mg)	0	25	0%	30	0%	35	0%	35	0%
Vitamin D (µg)	0.8	5	16%	5	16%	5	16%	5	16%
Vitamin E (mg α-tocopherol equiv)	2.4	4	60%	5	48%	5	48%	6	40%
Calcium (mg)	49	210	23%	270	18%	500	10%	700	7%
Phosphorus (mg)	208	100	208%	275	76%	460	45%	500	42%
Zinc (mg)	0.5	2	25%	3	17%	3	17%	4	13%
Iron (mg)	1.7	0.2	850%	11	15%	9	19%	10	17%
Magnesium (mg)	13	30	43%	75	17%	80	16%	130	10%
Selenium (µg)	41	12	342%	15	273%	25	164%	30	137%
Sodium (mg)	141	120	118%	170	83%	200-400	35-70%	300-600	24-47%
Potassium (mg)	138	400	35%	700	20%	2000	7%	2300	6%
Protein (g)	12.7	10	127%	10	127%	14	91%	20	64%
Iodine (ug)	43	90	48%	110	39%	90	48%	90	48%

Appendix 14.2 Recommended dietary intakes for children over 9 years [2]

	Per serve (2 medium eggs)	Boys				Girls			
	104g	9-13 years	%RDI	14-18 years	%RDI	9-13 years	%RDI	14-18 years	%RDI
Vitamin A (µg retinol equiv)	239	600	40%	900	27%	600	40%	700	34%
Thiamin (mg)	0.12	0.9	13%	1.2	10%	0.9	13%	1.1	11%
Riboflavin (mg)	0.5	0.9	56%	1.3	38%	0.9	56%	1.1	45%
Niacin (mg niacin equiv)	0	12	0%	16	0%	12	0%	14	0%
Vitamin B6 (mg)	0.05	1	5%	1.3	4%	1	5%	1.2	4%
Total folate (µg)	97	300	32%	400	24%	300	32%	400	24%
Vitamin B12 (µg)	0.8	1.8	44%	2.4	33%	1.8	44%	2.4	33%
Vitamin C (mg)	0	40	0%	40	0%	40	0%	40	0%
Vitamin D (µg)	0.8	5	16%	5	16%	5	16%	5	16%
Vitamin E (mg α-tocopherol equiv)	2.4	9	27%	10	24%	8	30%	8	30%
Calcium (mg)	49	1000-1300	4-5%	1300	4%	1000-1300	4-5%	1300	4%
Phosphorus (mg)	208	1250	17%	1250	17%	1250	17%	1250	17%
Zinc (mg)	0.5	6	8%	13	4%	6	8%	7	7%
Iron (mg)	1.7	8	21%	11	15%	8	21%	15	11%
Magnesium (mg)	13	240	5%	410	3%	240	5%	360	4%
Selenium (µg)	41	50	82%	70	59%	50	82%	60	68%
Sodium (mg)	141	400-800	17-35%	460-920	15-31%	400-800	17-35%	460-920	15-31%
Potassium (mg)	138	3000	5%	3600	4%	2500	6%	2600	5%
Protein (g)	12.7	40	32%	65	20%	35	36%	45	28%
Iodine (ug)	43	120	36%	150	29%	120	36%	150	29%

Appendix 14.3 Recommended dietary intakes for males [2]

	Per serve (2 medium eggs)	Males					
	104g	**19-50 yrs**	**%RDI**	**51-70 yrs**	**%RDI**	**> 70 yrs**	**%RDI**
Vitamin A (µg retinol equiv)	239	900	27%	900	27%	900	27%
Thiamin (mg)	0.12	1.2	10%	1.2	10%	1.2	10%
Riboflavin (mg)	0.5	1.3	38%	1.3	38%	1.6	31%
Niacin (mg niacin equiv)	0	16	0%	16	0%	16	0%
Vitamin B6 (mg)	0.05	1.3	4%	1.7	3%	1.7	3%
Total folate (µg)	97	400	24%	400	24%	400	24%
Vitamin B12 (µg)	0.8	2.4	33%	2.4	33%	2.4	33%
Vitamin C (mg)	0	45	0%	45	0%	45	0%
Vitamin D (µg)	0.8	5	16%	10	8%	15	5%
Vitamin E (mg α-tocopherol equiv)	2.4	10	24%	10	24%	10	24%
Calcium (mg)	49	1000	5%	1000	5%	1300	4%
Phosphorus (mg)	208	1000	21%	1000	21%	1000	21%
Zinc (mg)	0.5	14	4%	14	4%	14	4%
Iron (mg)	1.7	8	21%	8	21%	8	21%
Magnesium (mg)	13	400-420	3%	420	3%	420	3%
Selenium (µg)	41	70	59%	70	59%	70	59%
Sodium (mg)	141	460-920	15-31%	460-920	15-31%	460-920	15-31%
Potassium (mg)	138	3800	4%	3800	4%	3800	4%
Protein (g)	12.7	64	20%	64	20%	81	16%
Iodine (ug)	43	150	29%	150	29%	150	29%

Appendix 14.4 Recommended dietary intakes for females [2]

	Per serve (2 medium eggs)	Females									
	104g	**19-50 yrs**	**%RDI**	**51-70 yrs**	**%RDI**	**> 70 yrs**	**%RDI**	**Pregnant**	**%RDI**	**Lactating**	**%RDI**
Vitamin A (µg retinol equiv)	239	700	34%	700	34%	700	34%	800	30%	1100	22%
Thiamin (mg)	0.12	1.1	11%	1.1	11%	1.1	11%	1.4	9%	1.4	9%
Riboflavin (mg)	0.5	1.1	45%	1.1	45%	1.3	38%	1.4	36%	1.6	31%
Niacin (mg niacin equiv)	0	14	0%	14	0%	14	0%	18	0%	17	0%
Vitamin B6 (mg)	0.05	1.3	4%	1.5	3%	1.5	3%	1.9	3%	2	3%
Total folate (µg)	97	400	24%	400	24%	400	24%	600	16%	500	19%
Vitamin B12 (µg)	0.8	2.4	33%	2.4	33%	2.4	33%	2.6	31%	2.8	29%
Vitamin C (mg)	0	45	0%	45	0%	45	0%	60	0%	85	0%
Vitamin D (µg)	0.8	5	16%	10	8%	15	5%	5	16%	5	16%
Vitamin E (mg α-tocopherol equiv)	2.4	7	34%	7	34%	7	34%	7	34%	11	22%
Calcium (mg)	49	1000	5%	1300	4%	1300	4%	1000	5%	1000	5%
Phosphorus (mg)	208	1000	21%	1000	21%	1000	21%	1000	21%	1000	21%
Zinc (mg)	0.5	8	6%	8	6%	8	6%	11	5%	12	4%
Iron (mg)	1.7	18	9%	8	21%	8	21%	27	6%	9	19%
Magnesium (mg)	13	310-320	4%	320	4%	320	4%	350	4%	310	4%
Selenium (µg)	41	60	68%	60	68%	60	68%	65	63%	75	55%
Sodium (mg)	141	460-920	15-31%	460-920	15-31%	460-920	15-31%	460-920	15-31%	460-920	15-31%
Potassium (mg)	138	2800	5%	2800	5%	2800	5%	2800	5%	3200	4%
Protein (g)	12.7	46	28%	46	28%	57	22%	60	21%	67	19%
Iodine (ug)	43	150	29%	150	29%	150	29%	220	20%	270	16%

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