

# The role of Eggs in the diet of New Zealanders

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## EXECUTIVE SUMMARY

The objective of this report is to review literature on the major health areas that are relevant to eggs, draw conclusions and provide recommendations for various target audiences. Eggs are a popular food choice amongst the New Zealand population with each New Zealander consuming approximately 230 eggs per year. Over the years there have been mixed messages on potential negative health effects of eggs, in particular the effect of increased consumption on cardiovascular health. This is partly due to earlier epidemiological data that demonstrated a weak, positive association between dietary cholesterol and cardiovascular risk, and the fact that eggs are one of the richest sources of dietary cholesterol. However, public health messaging on egg consumption has evolved over the past years, with many national and international health organisations including regular egg consumption as part of a healthy, balanced diet in their dietary recommendations.

## FINDINGS

In total, 69 articles were evaluated, with key topics chosen based on the evidence available. The effect egg consumption has on serum cholesterol levels and cardiovascular disease risk has been the main health area of concern and consequently the one with the most evidence available. In addition, there is a significant amount of evidence available and continuing to emerge on the effect increased egg consumption has on weight management and diabetes, and the nutrient credentials of eggs.

Research is now suggesting, by the growing number of studies both observational and in controlled trials, that increased egg consumption has little or no association with increased serum cholesterol levels and increased risk of cardiovascular disease.

Research has also confirmed the nutrient credentials of eggs. Alongside the rich source of protein and 11 vitamins and minerals that eggs contain, they are also a rich source of choline, and increased consumption of eggs is shown in research to increase the serum concentrations of two carotenoids Lutein and Zeaxanthin. This is favorable, as Choline, Lutein and Zeaxanthin have been shown to have a protective role with many diseases and health conditions. Evidence has also shown a positive link between egg consumption and satiety, which is beneficial for weight management, although further research is recommended to confirm eggs as a beneficial food choice for long term weight management.

One key health area indicated in research as a potential concern in relation to increased egg consumption is diabetes. There is some evidence demonstrating increased egg consumption in diabetic participants is associated with increased cardiovascular risk versus non-diabetics. Studies have also demonstrated a negative association between egg consumption and the risk of diabetes itself. Additional case controlled and intervention research is recommended to further understand the link between increased egg consumption and diabetes.

The weight of evidence currently available supports eggs as a healthy food choice. This is evident in the current dietary recommendations compared to those from the 1960's and 1970's where eggs were commonly restricted, especially when concerning cardiovascular health. Many leading health organisations have reviewed their dietary guidelines for egg intake, with specific restrictions being removed, and including recommendations for up to six eggs per week or an egg a day as part of a healthy, balanced diet.

## RECOMMENDATIONS

### Micro-level

- Individual dietary advice required, with research in this review supporting the consumption up to one-two eggs per day as part of a healthy, balanced diet low in saturated fat for individuals not at risk of diabetes.

### Meso-level

- For people with diabetes, healthcare professionals should utilize the latest Australian Heart Foundation's recommendations for egg consumption with diabetics as guide – up to six eggs per week.

### Macro-level

- Opportunity for food industry to further research consumers understanding and knowledge on recommendations for egg intake.
- Opportunity for New Zealand government to include more specific guidelines and information on egg consumption to prevent potential confusion.

## CONCLUSION

The evidence presented in this literature review supports the inclusion of eggs as part of a healthy, balanced diet. Although additional research is warranted to further understand some potential negative health concerns related to increased egg consumption, the weight of evidence supports eggs as a nutritious food choice for the New Zealand population.

## PURPOSE OF THE PROJECT

The purpose of this review is to provide impartial, balanced and evidence-based information and advice to be utilized by a range of audiences including but not limited to; health professionals and health influencers, public health organisations, government agencies and the media. This was achieved through an extensive literature review of both research papers and credible health authorities' recommendations with a New Zealand perspective in mind.

The objectives were to:

1. Conduct an extensive literature review to determine up to date research and information available on the issue of eggs
2. Develop a balanced and evidence-based position paper
3. Provide supportable recommendations for further use within key audiences.

## INTRODUCTION

Eggs are a highly nutritious food and play an important part in a healthy balanced diet. They are an affordable source of high quality protein, contain almost all recognized vitamins and many essential minerals, are high in antioxidants such as lutein and zeaxanthine and the nutrient choline, and are a source of long-chain omega-3 fatty acids. Studies have also shown eggs increase satiety, which is beneficial for weight management.

Due to the flexibility of use, taste and nutritional benefits, eggs are a staple food in the New Zealand diet with egg farmers now producing approximately 1 billion eggs per year<sup>1</sup> and each New Zealander consuming approximately 230 eggs per year<sup>3</sup>. This makes New Zealanders amongst the highest per capita consumers of eggs in the world.

Even so, over past decades there has been public health messaging that has warned consumers about detrimental health effects of over consumption of eggs, specifically in relation to cardiovascular health. These warnings have meant past recommendations for egg intake by health authorities within New Zealand and around the world have been restrictive.

The concern for egg over-consumption is based on three observations;

- eggs contain high levels of cholesterol
- studies have shown that dietary cholesterol increases serum cholesterol
- high serum cholesterol is a key risk factor for the onset of heart disease.

However data from free-living populations now shows egg consumption is not associated with high cholesterol levels and in fact epidemiologic literature does not show any evidence that increased egg consumption is linked to increased risk of cardiovascular disease.

This movement in the scientific community has led to a shift in the public and professional opinion of eggs. The New Zealand Heart Foundation (NZHF) still recommends limiting intake to three eggs a week if at very high risk of heart disease, but does not restrict egg intake for the general population. Both the American Heart Association (AHA) and Australian Heart Foundation (AHF) have updated their healthy eating guidelines in recent years and have removed all specific guidelines to avoid or limit eggs in the diet. Instead they have focused on the decrease of foods high in saturated and trans fat, and in fact the AHF now state that up to 6 eggs can be consumed each week as part of a healthy diet low in saturated fat for cholesterol management.

## METHODOLOGY

In order to develop a position statement on the health credentials of eggs and any issues related to consumption, an extensive literature review was conducted to ensure that the position paper was evidence based and succinct.

Search engines such as ‘Medline’, ‘Google Scholar’ and ‘Science Direct’ were used, utilizing the following key words ‘eggs’, ‘cholesterol’, ‘cardiovascular disease’, ‘diabetes’, ‘weight management’, ‘satiety’, ‘lutein’, ‘zeaxanthin’ and ‘choline’.

The abstracts were reviewed, and then full copy of the study was sourced if considered suitable. Studies were included in literature review if there was significant strength of evidence, with a preference for controlled studies and prospective cohorts, only human

studies were considered, number of subjects were considered, as well as studies with relevant adjustments made in the data, and majority of studies were from the past 15 years.

The search criteria yielded the following articles; 19 reviews, 3 meta-analysis, 13 prospective (observational) studies, 25 controlled trials/interventions and 9 government reports or health authority position papers. A total of 69 articles all together.

## HISTORY

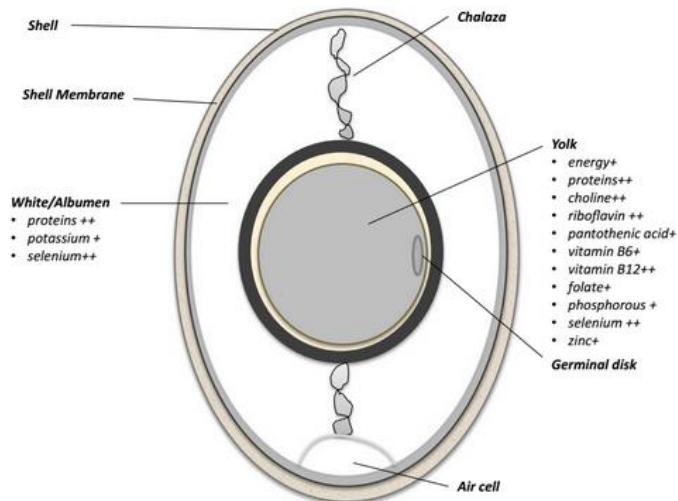
The consumption of eggs from a variety of birds, has been traced back to ancient times. However it was before 7500 BC, that the chicken as we know it today, was domesticated, and is believed to be a descendent of birds from the jungles of Southeast Asia. The inclusion of eggs in the diet has a long history in China, with the Greeks and Romans and throughout Europe, particularly in the middle ages. The opening of trade channels between China and England in the early 19<sup>th</sup> century, lead to major changes in the poultry industry, with major expansion and development of processes<sup>2</sup>.

Eggs from domestic birds (chickens) have been part of the New Zealand diet, providing an important and cost effective source of protein and nutrients since Captain Cook brought the first hens here in 1773. The consumer demand for eggs has doubled over the past century, with consumption of eggs increasing from approximately 100 eggs each person per year to now approximately 230 eggs per person per year<sup>3</sup>. This has meant farming methods have evolved to meet this demand, moving from mostly individually run coops and small free range operations to large scale farming via cage, barn or free range to meet the need for 1 billion eggs a year in New Zealand<sup>1</sup>.

New Zealand now has around 125 egg farms. From these farms, cage methods supply 89% of the eggs in New Zealand, free-range supply 9.7%, and barn production systems supply 1.4%. We are also fortunate that New Zealand has one of the most ideal egg farming environments in the world, free from many of the pests and diseases that occur in many other countries<sup>1</sup>.

## EGG COMPOSITION

Eggs are a highly nutritious food. The table<sup>4</sup> below illustrates the exact nutritional value and how it contributes to the diet. The data is based on a single medium egg and all values relate to the edible contents of the egg, excluding the shell.



**Figure 1 Illustration of the components of a chicken egg.** The nutrient contents of a whole large egg (60 g) are shown and are indicated by ++ if present at 50% or higher of the adequate intake (AI) or recommended dietary allowance (RDA) level for healthy, breastfed children 7–12 months of age or + if present at 20–50% of the AI/RDA for healthy, breastfed children 7–12 months of age.<sup>5</sup>

Eggs contain almost all key nutrients, with the exception of vitamin C. Eggs are a source of all B vitamins, in particular vitamins B12, riboflavin and folate. They also are a source of fat-soluble vitamins A and D as well as some vitamin E. Eggs are an important source of high quality and easily digestible protein, due to the amino acid profile of eggs.

**Table 1. Composition of Eggs**

	Per Egg (size 6) 51.3g	Per 100g	% of RDI for Adult Male
Energy (kJ)	274	534	2%
Protein (g)	6.7	13.1	10%
Fat (g)	4.2	8.1	N/A
Carbohydrate (g)	0.3	0.7	N/A
Dietary Fibre (g)	0	0	0%
Sugars (g)	0.3	0.7	N/A
Saturated Fat (g)	1.1	2.1	N/A
Monounsaturated Fat (g)	1.9	3.8	N/A
Polyunsaturated Fat (g)	0.4	0.7	N/A
Alpha-Linolenic Acid (g)	Trace	Trace	0%
Linoleic Acid (g)	0.3	0.6	2% (AI)
Cholesterol (mg)	203	395	N/A
Sodium (mg)	72	140	10% (AI)*

Iodine (ug)	23	45	15%
Potassium (mg)	72	140	2% (AI)
Calcium (mg)	26	51	3%
Phosphorus (mg)	97	190	10%
Iron (mg)	0.9	1.7	11%
Zinc (mg)	0.5	1.0	4%
Magnesium (mg)	Trace	Trace	0%
Selenium (ug)	12	23	17%
Vitamin A (ug)	110	220	12%
Thiamin (mg)	Trace	Trace	0%
Riboflavin (mg)	Trace	Trace	0%
Niacin (mg)	2.0	4.0	13%
Vitamin B6 (mg)	0.02	0.04	2%
Vitamin B12 (ug)	0.79	1.5	33%
Folate (ug)	64	130	16%
Vitamin C (mg)	0	0	0%
Vitamin D (ug)	0.77	1.5	15% (AI)
Vitamin E (mg)	0.84	1.6	8% (AI)
Choline (mg)	146	285	27% (AI)
Pantothenic (mg)	0.72	1.4	12% (AI)

Source: *The Concise New Zealand Food Composition Tables. 10th edition, 2013.* RDI based on male 31-50yr, 1.9m, 80kg, 13,400kJ/day. \*Average sodium RDI taken from range 460-920mg/day

## EGGS AND CHOLESTEROL

Eggs are a high cholesterol food, with each egg containing approximately 200mg<sup>4</sup>. Nutrition guidelines from the AHA recommend limiting dietary cholesterol intake to <300mg/day<sup>5</sup>. The predominate source of dietary cholesterol in the NZ diet is foods of animal origin including meat, eggs and dairy products. Of those sources, eggs and egg dishes contribute the largest proportion at 13% of the cholesterol in the in New Zealand adult's diet. Males aged 51 – 70 and females aged 19 – 30 and 71+ had the highest percentage of their cholesterol intake from eggs and egg dishes with 15.7%, 15.8% and 16.0% respectively<sup>6</sup>.

Elevated cholesterol levels in the New Zealand population remain a concern. According to the 2012/2013 NZ Health Survey update one in nine NZ adults are on medication for high cholesterol. This is the equivalent to 11.2% of the NZ adult population (15 years upwards) and is a significant increase from the 2006/2007 survey where 8.4% of NZ adults had high cholesterol and were on medication. This result is raised significantly in the older adult age group (75 years and older), whereby 33% are medicated for high cholesterol<sup>7</sup>.

Cholesterol intakes were evaluated as part of the NZ Adult Nutrition Survey 2008/2009.

- The usual median daily cholesterol intake for the total adult population was 262mg.
- Adult males had a higher median daily cholesterol intake of 316mg
- Adult females median daily cholesterol intake was 216mg.
- The median cholesterol intake per day increased in the Maori population with 410mg for males and 262mg for females,
- The Pacific population results were 363mg median daily intake for males and 262mg for females<sup>6</sup>.

It is well documented that high plasma cholesterol levels, particularly high low density lipoprotein (LDL) cholesterol levels, are a key risk factor for the development of heart disease<sup>8</sup>. However, research demonstrating the effect dietary cholesterol has on serum cholesterol is inconsistent and limited, ranging from positive associations to no effect at all<sup>9</sup>. Even with studies demonstrating a positive association of dietary cholesterol with serum LDL-cholesterol, there is a large variability in an individual's response to dietary cholesterol<sup>9</sup>, and, they are challenged by the many years of epidemiological research reporting dietary cholesterol has no clinical significant impact on Cardiovascular (CVD) risk<sup>10, 11</sup>.

More current studies are showing dietary cholesterol intake produces only modest increases/effects on serum lipid levels<sup>12</sup>, especially when compared to the impact that saturated fat and trans fatty acids have on raising LDL cholesterol. Furthermore, dietary cholesterol impacts on serum cholesterol levels are seen in mostly population sub groups.<sup>10</sup> Dietary cholesterol increases both LDL and high density lipoprotein (HDL) cholesterol in the plasma thereby having little impact on the LDL: HDL ratio which is a significant indicator of heart disease<sup>11</sup>.

The past concern about egg consumption has been based mostly on the connection between eggs and cholesterol intake and the link to potential CVD risk. This caused leading health authorities in New Zealand and across the globe, to place restrictions on recommended egg intakes. Nutrition guidelines such as those from the NZHF recommended limiting the intake of eggs to no more than three eggs per day if you are at high risk of CVD<sup>13</sup>. The AHA up until their revision of nutrition guidelines in 2000 stated that no more than 3 egg yolks should be

consumed each week<sup>5</sup> and in fact continue to advise that people with CVD should consume <200mg cholesterol per day<sup>77</sup>.

These intake recommendations have been challenged by research investigating the effects of both dietary cholesterol and egg consumption on serum cholesterol.

Clinical interventions have reported an increase in cholesterol intake results in an increase in both LDL and HDL cholesterol in those subjects that respond to dietary cholesterol challenges<sup>14</sup>. In addition, there are examples in which dietary cholesterol resulted in an increase in HDL cholesterol only with no effect on LDL cholesterol observed alongside certain conditions such as weight loss interventions and other factors<sup>14</sup>.

Although recent meta-analysis examining the impact of eggs or dietary cholesterol on serum cholesterol levels indicated an increase of 100mg cholesterol per day increases serum cholesterol by 0.06mmol/L (LDL serum cholesterol by 0.05mmol/L and HDL cholesterol by 0.01mmol/L)<sup>15</sup>, subsequent studies have emphasized the importance of taking into the account the background diet. A 100mg increase in dietary cholesterol, alongside a background diet high in saturated fat produced a larger increase in serum LDL cholesterol of 0.061 +/- 0.006mmol/L increase and an increase of only 0.036 +/- 0.004mmol/L with a diet low in saturated fat<sup>16, 17</sup>. In addition, it is now recognized we must view dietary effects on serum cholesterol from its impact on the atherogenic LDL cholesterol as well as the anti-atherogenic HDL cholesterol. As already mentioned, it is the ratio of LDL: HDL that is significant to the risk of CVD, and on average the ratio change per 100mg/day increase in dietary cholesterol is from 2.60 to 2.61 which is predicted to have little impact on CVD risk<sup>11</sup>.

Dawber et al in 1982 utilized the Framingham cohort to further investigate specifically the effects of egg intake on serum cholesterol. 912 males and females were examined and their diet histories evaluated. This review revealed a lack of association between egg consumption and serum cholesterol levels. This was further demonstrated by the fact that men in the highest third of egg intake had identical cholesterol levels (6.08mmol/L) to the men in the lowest third of intake level. In addition, women with the lowest intake of eggs had slightly higher cholesterol levels than those with a higher intake of eggs, 6.34mmol/L compared to 6.26mmol/L<sup>18</sup>.

There have been further randomized controlled trials (RCT) continuing to demonstrate the lack of significant impact egg intake has on serum cholesterol.

Katz et al<sup>19</sup>, demonstrated no effect on total serum cholesterol and endothelial function in healthy adults with the addition of two eggs daily to the diet over a six week period. Goodrow et al RCT in 2006, studied 33 men and women older than 60 years of age. They demonstrated the consumption of one egg per day over a five week period causes no effect on total, LDL and HDL serum cholesterol levels<sup>20</sup>. Wenzel et al in a study of 24 women aged between 24 – 59 years showed neither mean total serum cholesterol nor total cholesterol (TC): HDL significantly increased following the consumption of six eggs per week over a 12 week period<sup>21</sup>. In a more recent 2012 study, Klangjareonchai et al concluded that in hyperlipidemic adults being treated with lipid-lowering medication, the addition of 3 eggs per day to their regular diet increases the HDL cholesterol but decreases the LDL: HDL ratio<sup>22</sup>.

There are several studies that have demonstrated positive effects on lipid profiles with increased egg consumption alongside other dietary modifications. Mutungi studied 28

overweight/obese males aged 40 – 70 years to examine how egg intake affects serum cholesterol levels within a carbohydrate restricted diet (CRD). Even with the addition of three eggs per day (640mg additional dietary cholesterol per day), there was no change to serum LDL cholesterol and LDL: HDL ratio. However the HDL serum cholesterol increased<sup>23</sup>. Blesso et al conducted similar studies in adults with metabolic syndrome. The addition of three eggs per day alongside a CRD over a 12 week intervention period compared to egg substitute consumption, lead to improved lipid profiles including increased HDL serum cholesterol<sup>24</sup>.

Although there are previous studies showing dietary cholesterol can increase serum LDL-cholesterol<sup>10, 15</sup> there is now substantial research available to conclude that an increase of dietary cholesterol, including from eggs, has little or no effect on serum cholesterol levels and, more importantly, LDL:HDL ratio and is highly variable between individuals. In some circumstances alongside other dietary modifications, it leads to increase in HDL serum cholesterol. Studies show saturated fat intake has more impact on serum cholesterol levels, which is in line with dietary recommendations from leading heart associations around the world. The combination of these studies, further supports the suggestion eggs can be consumed as part of a heart healthy diet low in saturated fat, and have no negative effects on serum cholesterol<sup>25</sup>.

## EGGS AND CARDIOVASCULAR DISEASE

Cardiovascular disease, including heart, stroke and blood vessel disease, is still a leading cause of death in New Zealand, causing 30% of deaths each year. In addition, one in twenty adults (176,000 adults) have been diagnosed with coronary heart disease<sup>26</sup>.

Increased egg consumption has long been thought to be associated with a higher risk of cardiovascular disease. As already discussed this was due to the high amount of cholesterol found in eggs. The strength of evidence available was based on demonstrating a high serum cholesterol level is a key risk factor for the onset of cardiovascular disease<sup>10</sup>. But an important question to examine is the direct link of dietary cholesterol to increased CVD risk.

As eggs are considered the richest source of dietary cholesterol in the western diet, with a medium egg containing approximately 200mg cholesterol, they have been commonly chosen as a vehicle of choice to deliver the dietary cholesterol required for human intervention studies, and a marker of dietary cholesterol in prospective cohort studies<sup>10</sup>.

There are several RCT's that have challenged the impact of dietary cholesterol and egg consumption on serum cholesterol levels, and decades of reputable research that confirm the negative effect of serum cholesterol levels on CVD risk. However, to date there is no RCT data on the direct link of egg consumption and increased CVD risk, but a growing number of prospective studies<sup>9,18,27,29,31,32</sup> and meta-analysis<sup>78</sup>.

One of the first of these prospective studies was carried out by Hu et al who did so in response to the lack of epidemiologic studies on egg consumption and increased risk of CVD. Two cohorts were examined – the Health Professionals Follow-up Study (1986 – 1994) and the Nurses' Health Study (1980 – 1994). This included a total of 37,851 men aged 40 – 75 years and 80,082 aged 34 – 59 years, who were CVD, diabetes, hypercholesterolemia and cancer free. Detailed food frequency questionnaires from both large cohorts were examined to determine egg consumption and adjustments were made for many dietary and lifestyle

factors such as smoking, dietary fibre intake and bacon consumption. Data concluded that the inclusion of up to one egg per day in the diet is unlikely to have a substantial effect of the risk of CVD among healthy men and women. Hu et al discussed the equation devised by Keys and Parlin, which, based on the cholesterol intake from an egg of 200mg (with a 7560kJ background diet), results in 4% increase in total serum cholesterol for a normocholesterolemic person. Assuming an increased cholesterol level is the only effect of the egg consumption, this would lead to an 8% increase in CVD risk which is considered too small an effect to be detected in most epidemiologic studies or clinical trials<sup>27</sup>. One important factor in Hu et al's study was the sheer size made it large enough to examine a variation of background diets, including low dietary cholesterol intake from non-egg sources. This is important as we want to investigate the fact total cholesterol intake may not be different for egg and non-egg eaters due to other dietary sources in their background diet<sup>28</sup>.

Zazpe et al investigated the association between egg consumption and the incidence of CVD, utilizing a prospective dynamic free-living Mediterranean cohort consisting of 14,185 university graduates. This observation study concluded the data they collected suggested higher intake of eggs was not associated with increased CVD incidence (Hazard ratio 1.10, 95% confidence interval: 0.46 – 2.63). Adjustments were made for age, sex, total energy intake, adherence to Mediterranean dietary patterns and other cardiovascular risk factors<sup>29</sup>. Zazpe et al, proposed several mechanisms that could explain the lack of association between egg consumption and increased CVD risk. For example, genes play an important role in regulating cholesterol intake<sup>10, 11, 30</sup> although there are some population sub groups such as people with diabetes who may benefit from a low cholesterol intake due to abnormalities in the way cholesterol is transported<sup>27, 31</sup>. In addition, it is not only dietary cholesterol from eggs that could affect CVD risk, but the total cholesterol intake from the entire dietary pattern<sup>30</sup> and finally the egg nutrient composition could be protective, being a good source of unsaturated fats and lower saturated than many other protein foods<sup>26, 30</sup>.

Djousse and Gaziano in 2008 examined the association between egg consumption and risk of CVD mortality by reviewing the large cohort of 21,327 male participants from the Physicians Health Study. The conclusions were mixed, with consumption of ≤6 eggs per week having no major effect on CVD risk and mortality, whereas the consumption of more than seven eggs per week is associated with a moderately greater risk of total mortality. Participants with diabetes demonstrated greater risk of all-cause mortality with any egg consumption<sup>9</sup>. An additional study Djousse and Gaziano carried the same year also utilised the Physicians Health Study cohort, however looked specifically at risk of heart failure in relation to egg consumption. This study also had mixed results, with again no associated risks of heart failure of up to 6 eggs per week, however ≥7 eggs per week was associated with increased heart failure risk. Adjustments were made for age, body mass index, smoking, alcohol consumption, exercise and history of atrial fibrillation, hypertension, valvular heart disease and hypercholesterolemia. Conclusions drawn from this study are that infrequent egg consumption would not lead to an increase risk of heart failure, however the consumption of ≥1 per day has shown to increase risk of heart failure amongst male physicians in the US<sup>79</sup>.

One recent prospective study examined the association between egg consumption, total cholesterol concentration and the increased risk of CVD, in a population group with high egg consumption. Nakamura et al studied the Japan Public Health Center-based prospective study cohort including a total of 90,735 participants (19,856 men and 21,408 women aged 40 – 59

years in cohort 1 and 23,463 men and 26,008 women aged 40 – 69 years in cohort 2). In this study, men and women were combined for the analyses. Four different egg intake groups were examined. It was concluded an intake of eggs almost daily was not associated with any increase in Coronary heart disease (CHD) incidence. In addition, an inverse correlation was found between egg consumption and the occurrence of hypercholesterolaemia in both sexes and in both cohorts, most likely due to the fact hypercholesterolaemic participants would avoid eggs due to the cholesterol content<sup>32</sup>.

These conclusions differed slightly from the earlier research carried out by Nakamura et al in 2004. Utilising the NIPPON DATA80 database, which followed a total of 5186 women and 4077 men over a 14 year period, Nakamura et al analysed the link between egg consumption, serum cholesterol and cause-specific and all-cause mortality. In this study the subjects were categorized into 5 egg consumption groups based off their response to a questionnaire – seldom, 1-2 eggs/week, 1 egg/day, 1-2eggs/day, and ≥2 egg/day. Results showed that among women, there was a tendency for lower mortality due to stroke, ischemic heart disease and cancer in the 1-2 eggs/week group compared to the 1 egg/day group, which may have led to significantly fewer all-cause deaths. This was not seen in any of the men groups. Nakamura et al concluded that it's possible that limiting egg consumption can have some health benefits, particularly with women in geographic areas where egg consumption contributes significantly to the total dietary cholesterol intake<sup>80</sup>.

A recent meta-analysis by Rong et al in 2013 investigated and quantified the potential dose-response association between egg consumption and coronary heart disease and stroke risk. This meta-analysis reviewed specifically prospective cohort studies, 8 articles and 17 reports in total were eligible. One of the strengths of this meta-analysis was the large sample size and long follow-up periods, which increased the statistical significance and ability to identify possible associations. The results from this meta-analysis demonstrate that higher egg consumption is not associated with increased risk of coronary heart disease and stroke. There is a suggestion in subgroup analyses of a potential positive association between increased egg consumption and risk of coronary heart disease in people with diabetes. It is suggested in the meta-analysis that further research is warranted to confirm the subgroup results, but with larger sample sizes and longer follow-up times<sup>78</sup>.

Although there is some evidence available showing a positive association between increased egg consumption and CVD risk<sup>79,80</sup>, the majority of studies reviewed demonstrate the strength of evidence against a relationship between egg consumption and increased CVD risk. There have been numerous hypotheses developed over the years as to why this relationship isn't considered clinically significant. It is possibly due to the many other nutrients contained in eggs, which will be discussed further on in the review. In particular, foods rich in dietary cholesterol are most likely also high in saturated fat and trans fatty acids. Therefore the resulting increase in serum cholesterol from these foods is most likely due to the link between saturated fat and trans fat and increased serum cholesterol levels and CVD risk, which is supported by a wealth of evidence<sup>11</sup>. Eggs however, have a lower saturated fat level relative to other common animal based protein foods for example chicken drumstick legs or sirloin steak<sup>4</sup>, and are good sources of poly and mono unsaturated fats. This makes it a perfect food to study for the effects of dietary cholesterol, and challenges dietary recommendations that restricting egg consumption plays a role in preventing CVD<sup>32</sup>.

## EGG AND DIABETES

Diabetes is a disease that continues to be a serious public health problem affecting many New Zealanders. Over 243,000 New Zealanders suffer from either Type 1 or Type 2 Diabetes. Type 2 Diabetes in particular is associated with many cardiovascular disease risk factors such as high blood pressure and dyslipidaemia<sup>33</sup>.

Studies researching the association between egg consumption and diabetes are limited, and have shown inconsistent results. Several prospective studies, utilising epidemiological data have researched the association between egg consumption and increased cardiovascular disease risk and stroke. They established that increased egg consumption increased the risk of CVD and stroke in study participants with diabetes and concluded increased egg consumption and its effects among people with diabetes warrants further investigation<sup>9,27,31</sup>.

One such study was Hu et al's prospective study utilising two large prospective cohort studies of men and women, the Health Professionals Follow-up study, and the Nurse's Health study. The study aimed to look further into any possible positive associations between 12 additional subgroups, including those with diabetes. The diabetes subgroup was the only one of the 12 to show any evidence of a positive association with higher egg consumption<sup>27</sup>. This association was again demonstrated in Qureshi et al's prospective study of data from the First National Health and Nutrition Examination Survey (NHANES-I), a prospective cohort of 9734 adults aged between 25 – 74 years. In their subgroup analysis, higher egg consumption was observed to be associated with increased risk of coronary artery disease and myocardial infarction among participants with diabetes<sup>31</sup>.

Djousse and Gaziano's prospective study on the cohort from the Physicians' Health Study, also noted a stronger association between increased egg consumption and cardiovascular mortality within the diabetic subjects in the study population. Through stratified analysis of prevalent diabetes at baseline, it was shown physicians with diabetes, who consumed ≥seven eggs per week compared to <one egg per week had a two times greater risk of all-cause mortality. In addition, the data also suggested a greater risk of myocardial infarction amongst male physicians with diabetes<sup>9</sup>.

More recent research, including controlled trials and prospective studies have studied the effect of egg consumption directly on increased risk of diabetes. The majority of these studies came to corresponding conclusions that increased egg consumption lead to increased risk of diabetes.

The prospective study by Djousse et al in 2008, collected data from two completed randomised trials, 20,703 men from the Physicians' Health Study I and 36,295 women from the Women's Health Study. There was an observed increase in risk of type 2 diabetes of 58% in men and 77% in women with consumption of one or more eggs per day, compared to no egg consumption. This raised concerns of the possibility of undesirable health effects from high egg intakes<sup>34</sup>.

The prospective study carried out by Shi et al researched a Chinese population of 2849 adults aged 20 years and older. The results demonstrated after the adjustment of many factors including age and family history of diabetes, that the consumption ≥one egg per day was positively associated with diabetes risk, particularly in women<sup>35</sup>.

Radzeviciene et al carried out a case-controlled study to determine whether or not there is an association between egg consumption and the risk of type 2 diabetes. The results demonstrated twice the risk of type 2 diabetes for individual's consuming 3 – 4.9 eggs per week, and three times the risk of type 2 diabetes with those consuming ≥five eggs per week, compared to those consuming <one egg per week<sup>36</sup>.

*One exception to the studies that have supported an association between egg consumption and increased risk of diabetes is a prospective study by Djousse et al in 2010. The objectives of this study were to assess the association between egg intake and incidence of diabetes in older adults. It utilised a prospective study of 3898 men and women from the Cardiovascular Health Study. Egg consumption was assessed via a picture-sorted food questionnaire and adjusted relative risks estimated. The conclusions of this study were in a cohort of older adults with limited egg intake, there is no association between egg intake and increased risk of type 2 diabetes<sup>37</sup>. One possible reason for the difference in results compared to the majority of research available could be due to a limitation in the study that high intakes of eggs could not be specifically evaluated as few people in this cohort consumed such amounts. Therefore, the fact there was no effect on diabetes risk could be due to the limited amount of eggs the participants consumed.*

Although there has been some evidence demonstrating a negative relationship between increased egg consumption and diabetes, the evidence is limited, inconsistent and from epidemiological, not clinical studies. As indicated in a majority of the studies reviewed, further research would be beneficial, in particular more clinical research, in order to make more formal recommendations. However, it is important to note that the National Heart Foundation of Australia have recently updated guidelines on egg consumption for diabetics, which recommend up to six eggs a week can be consumed without any adverse effects of cardiovascular risk<sup>76</sup>. In addition, this intake guideline is also confirmed by Diabetes NZ (Auckland) as their recommendation to diabetic patients<sup>81</sup>. It is recommended that until further clinical studies are carried out, professionals when giving advice use this as a guide.

## EGGS AND WEIGHT MANAGEMENT

When addressing weight management, satiety is an important tool. The macronutrient dietary protein has been identified with a positive association to satiety<sup>38-40</sup>. As eggs are a rich source of high quality protein and are also low in energy, contributing only 7% of an individual's daily energy requirements, they therefore have a two-fold benefit as a food choice for weight management. Holt et al developed a satiety index reported in the European Journal of Clinical Nutrition<sup>41</sup> which ranked many popular foods in how they compared to a slice of white bread which carried a rank of 100. Eggs were shown to have a satiety index 50% greater than other ready to eat breakfast cereals as well as white bread. Holt et al also demonstrated that eggs have an overall higher satiety index value than popular breakfast foods in non-obese subjects<sup>42</sup>.

Due to their nutritional composition, research has emerged over the past few years establishing eggs as an effective food choice in weight management. Vander Wal et al first studied the benefit of an egg breakfast in comparison to an isocaloric, equal weight bagel based breakfast. Their hypothesis was the egg breakfast would produce greater satiety, and reduce both perceived cravings as well as subsequent energy intake. Thirty women participated, between the ages of 25 – 60 years with a BMI of at least 25 kg/m<sup>2</sup>. Participants consumed either an egg or bagel based breakfast. They would then consume lunch 3.5 hours later. Conclusions from this study demonstrated that the egg based breakfast lead to greater satiety, and energy intake remaining lower for the entire day ( $p<0.05$ ) and the next 36 hours ( $p<0.001$ )<sup>43</sup>. Vander Wal et al's second study established an egg breakfast, again compared to an isocaloric bagel based breakfast, does enhance weight loss when combined with an energy reduced diet in overweight and obese participants. In this study, otherwise healthy overweight or obese individuals were divided into four groups, an egg and egg diet group, as well as bagel and bagel diet group. The two diet groups were recommended a 1000 kcal energy deficit low fat diet, with the remaining two groups remaining free living<sup>44</sup>.

Another study researched the hypothesis eating eggs for breakfast would significantly increase subsequent satiety and energy intake for the remainder of the day. In this crossover trial, 21 men aged 20 – 70 years consumed two isocaloric test breakfasts, either egg or bagel based, in a random order separated by a week. Participants then consumed a buffet lunch until satisfied, 180 minutes after breakfast. Visual Analog Scales (VAS), food intake surveys and blood tests were completed. Results concluded that fewer calories are consumed following an egg breakfast compared to the bagel breakfast ( $p<0.01$ ). The VAS established that participants were hungrier and less satisfied 3 hours post bagel breakfast in comparison to egg breakfast ( $p<0.01$ )<sup>45</sup>.

Pombo-Rodrigues et al carried out similar research, comparing an egg based lunch with other meals in a randomized, three-way crossover study. Thirty-one male and female participants consumed one of the following isocaloric lunches - omelette, jacket potato or chicken sandwich. VAS was used to record satiety, and the energy intake from the following meal was recorded. The egg based lunch demonstrated increased satiety, particularly compared the jacket potato, however no effect was seen on the subsequent energy intake. Conclusions were drawn that an egg based meal increases satiety compared to a carbohydrate based meal and could help towards reducing the amount of energy consumed between meals<sup>46</sup>.

Finally, a three way, crossover design study carried out by Fallaize et al reached the same conclusion of egg based meals increasing satiety and reducing hunger. Thirty men consumed either eggs on toast, cornflakes with milk and toast or a croissant and orange juice, on three separate occasions, separated by one week. Feelings of satiety, hunger, fullness and desire to eat were rated and recorded at 30 minute intervals utilising VAS and energy intake at subsequent meals were assessed. Results again demonstrated increased satiety, less hunger and a lower desire to eat after the egg based breakfast was consumed, compared to the cornflake breakfast ( $p<0.02$ ), and croissant breakfast ( $p<0.0001$ ). The egg breakfast also lead to significantly less energy intake at subsequent meals. It was noted the breakfast having the most effect on satiety and subsequent energy intake had the highest protein and lowest carbohydrate content compared to the alternative breakfasts<sup>47</sup>.

Further research is warranted on the benefits of eggs as a food choice for weight management. There is still a lack of evidence on the effects eggs have on satiety for long term weight loss and on the role of eggs within the totality of a meal i.e. do they work synergistically or separately to other foods such as bread, and there is a need for further understanding of gastric emptying after an egg based meal and relationship with gut hormones<sup>26</sup>. However the research that has taken place to date, gives evidence to suggest confidently egg intake should be encouraged during weight loss or management due to its positive effect on satiety and subsequent energy intake. This could be due to the high protein content of eggs, and potentially also due to the specific amino acid composition and digestibility of eggs, as when compared to other protein based foods such as chicken, the satiety effects favoured egg based meals<sup>46, 48</sup>.

## EGGS AND CHOLINE

Choline has only recently been recognized as a nutrient we need to consume daily, for good health. Choline is found in a wide variety of foods both plant based sources and animal based sources. This includes foods such as soy, wheat germ, broccoli, almonds as well as eggs, meat and milk<sup>2</sup>. Through research it has been shown to have many benefits for various diseases and health conditions, such as neurodevelopment, cognitive function, neural tube defect incidence<sup>49-51</sup>, cardiovascular disease, through association with decreased plasma levels of homocysteine and inflammatory factors<sup>52</sup>, breast cancer<sup>53</sup> and has a role in the epigenetic changes via the methylation of DNA<sup>54</sup>.

In 1998 the USA Institute of Medicine (IOM)<sup>55</sup> added choline to the list of required nutrients and developed Adequate Intakes (AI) for both females and males in a range of age groups. Adult females 19+ years required 425mg/day, with adult males requiring 550mg/day. Pregnant and lactating women have high AI at 450mg and 550mg respectively<sup>56</sup>. Data for dietary intakes of choline had been limited, but in the USA has been shown to be inadequate in most adult's diets<sup>57</sup>. Data has been unavailable in New Zealand (NZ). However, in 2013 Mygind et al utilised the baseline dietary data collection for a folate intervention trial that took place in NZ between July 2008 and May 2009. The objective of this study was to estimate the usual intake and food sources of choline and betaine (metabolite for choline) in NZ women of reproductive age. The study collected data for dietary intake which consisted of a 3-day weighed food record, from a sample of 125 women aged between 18 – 40 years. Women were excluded if they were pregnant, lactating or were planning to be pregnant in the coming

12 months. Usual choline and betaine intake distributions were then determined. Results showed that the mean total dietary intake for choline was 315mg and daily energy intake was 1843kcal, with 16% of the participants meeting or exceeding the estimated AI for adult women. Eggs were found to be the top contributor to choline intake, providing 13% of the total choline intake in the women's diets. Other top food contributors were red meat at 10%, milk at 8%, and bread at 5.5% and chicken at 4.5%<sup>58</sup>.

This study confirms previous reports that suggest choline intakes are suboptimal in a large proportion of the population. It also confirms that eggs are the top contributor to choline intake and a major source of choline, containing 144mg per medium egg and provides more choline per kcal than any other foods.

There has been some research carried out on trimethylamine-N-oxide (TMAO). This research is primarily looking at foods that increase serum TMAO levels, and the effect these serum levels have on cardiovascular disease (CVD) risk factors such as atherosclerosis or inflammation and oxidation of low-density lipoproteins. Recent research by Zhang et al has shown that increased egg consumption ( $\geq 2$  eggs/day), which is rich in choline, increased serum TMAO levels<sup>82</sup>, however previous research had differing conclusions. In this study, 46 individual foods were investigated and only fish and other sea-products consumption lead to increases in urinary TMAO levels<sup>83</sup>. Zhang et al's research also studied the potential effect that TMAO has on CVD risk factors as discussed. Their conclusions from this study were that additional research is recommended to further understand this effect. This is understandable considering the research is only preliminary and this study only comprised of 6 participants, which is a significant limitation<sup>82</sup>.

New Zealand has now included choline in their RDI/AI charts, with the AI for men at 550mg/day, women 425mg/day, ranging between 415 – 440mg/day for pregnant women and 525 – 550mg/day for women who are lactating<sup>4</sup>. Further research is warranted before any concrete conclusions are made on TMAO and any potential negative influence it has on cardiovascular disease.

## EGGS AND LUTEIN AND ZEAXANTHIN

One of the explanations given by researchers as to why there seems to be no relationship between egg consumption and increased CVD risk, is the additional nutrients found in eggs. This includes choline discussed above and also the antioxidants Lutein and Zeaxanthin.

Lutein and Zeaxanthin are oxygenated carotenoids with antioxidant capabilities that accumulate in the macular region of the retina. These carotenoids have a role in reducing the risk of cataracts and age-related macular degeneration, and are possibly protective against some cancers. There is also evidence both experimental and epidemiological, suggesting that lutein and zeaxanthin have a potential role in reducing risk for cardiovascular disease and stroke<sup>59</sup>.

Eggs are a rich source of lutein and zeaxanthin, they are also found in many vegetables such as spinach, kale, peas, broccoli, onions and corn.

**Table 2. Content of Lutein and Zeaxanthin in Chicken Egg Yolk<sup>1</sup>**

	Lutein <sup>2</sup>	Zeaxanthin <sup>2</sup>	Total
µg/yolk	292 ± 117	213 ± 85	505
µg/mg cholesterol	1.19 ± 0.32	0.87 ± 0.23	2.06
µg/100 g yolk	1723 ± 690	1257 ± 502	2980

<sup>1</sup> From Handelman *et al.* [6].

<sup>2</sup> Mean ± SD values.

Ribaya-Mercado, J.D. & Blumberg, J.B. *Lutein and zeaxanthin and their potential roles in disease prevention*. *Journal of American College of Nutrition* **23**, 567S-587S (2004)

Due to the lipid matrix of egg yolk, lutein and zeaxanthin are more bioavailable from eggs than from plant sources such as spinach<sup>60</sup>. This was observed by Chung et al in an intervention trial (with crossover design) from 2004. Participants consumed the same total amount of lutein from various sources. The serum lutein levels were highest after the consumption of eggs versus spinach and supplements. This suggests lutein derived from eggs is more bioavailable, even compared to other foods with higher lutein content<sup>60</sup>.

There are further studies confirming egg consumption will increase serum lutein and zeaxanthin levels. Goodrow et al investigated the effect of egg consumption on serum concentrations of lutein, zeaxanthin and lipids. The randomized cross-over design trial studied 33 men and women 60 years and above. They consumed one egg per day for five weeks, then no eggs for the following five weeks. There was a significant increase in serum concentrations of lutein and zeaxanthin intervention compared to the no-egg intervention, with the addition of one egg per day increasing lutein and zeaxanthin concentrations by 26% ( $p<0.001$ ) and 38% ( $p <0.001$ ) respectively. This increase took place with no effect on serum lipids and lipoprotein cholesterol concentrations<sup>20</sup>.

The findings of this trial support the findings of Handelman et al. The objective of this trial was to also determine whether supplementation of egg yolk in the diet could increase lutein and zeaxanthin serum concentrations. 1.3 egg yolks per day were supplemented into two different baseline diets, containing 20% of energy from either beef tallow or corn oil. Results demonstrated that egg yolks are a high bioavailable source of both carotenoids, with an increase in serum lutein and zeaxanthin of 28% ( $p < 0.05$ ) and 142% ( $p < 0.001$ ) respectively in the beef tallow diet and 50% ( $p < 0.05$ ) and 114% ( $p < 0.001$ ) in the corn oil diet. A conclusion from this trial is egg yolks are a beneficial addition to the diet<sup>61</sup>.

A recent trial also confirmed egg yolk as an important source of the two carotenoids lutein and zeaxanthin. It was further observed that egg yolk, due to its high content of these carotenoids, is an important food choice for population groups at higher risk of cardiovascular disease and type 2 diabetes, due to its positive association to metabolic syndrome<sup>24</sup>. In this study, participants consumed 3 whole eggs per day or an equivalent egg substitute as part of a carbohydrate restricted baseline diet for 12 weeks. During the post intervention period, the egg consuming group had significant increases in serum lutein and zeaxanthin of 21% and 48% respectively, with no significant increases in the egg substitute group<sup>62</sup>

Although there is currently no consensus on a daily recommended intake for lutein and zeaxanthin, research that has taken place over the past decade indicates these carotenoids are beneficial for optimal health and have protective role to play in many health conditions and diseases. As eggs are an excellent source of these carotenoids, this is another reason they should be recommended to be a regular inclusion in a healthy diet. However it is noted, that there is research available showing inconsistent results in egg contribution to serum lutein and zeaxanthin concentrations<sup>63</sup>, therefore, it would be valuable to see further research on this topic.

## EGGS AND GUIDELINES FOR RECOMMENDED INTAKES

Dietary recommendations for egg intake over the past decades, have been heavily influenced by the existing guidelines in each country for reducing total fat, saturated fat, cholesterol and increasing polyunsaturated fat intake. If we take the US as an example, in the 1970's the public were advised via dietary guidelines, to avoid foods high in saturated fat and cholesterol, and specifically avoid consumption of eggs. The Inter-Society Commission for Heart Disease Resources stated in 1970 'Ingestion of two eggs a day will seriously hamper dietary programs aimed at reducing serum cholesterol. Consequently, the public should be encouraged to avoid egg yolk consumption'. The American Heart Association (AHA) also advocated for egg intake restriction, with their 1973 statement 'The association noted that dietary cholesterol be limited to no more than 300mg per day, and recommended that individuals eat no more than 3 egg yolks per week'<sup>10</sup>.

These recommendations were driven by the hypothesis that dietary cholesterol increases heart disease risk, which is based on the observations that dietary cholesterol increases serum cholesterol, and that increased serum cholesterol is a risk factor for heart disease. Therefore, as eggs are rich in cholesterol, they are a food that should be avoided to reduce risk of heart disease. Research in more recent years has begun to question whether it is in fact dietary cholesterol that has an antagonistic role in heart disease risk, or is it more likely the saturated and trans fat commonly found in foods also high in dietary cholesterol leads to increased risk<sup>64</sup>. This hypothesis has been demonstrated in more recent research specifically studying any direct association between eggs and cardiovascular disease risk. These studies have concluded that there is very little evidence to suggest that eggs, a food rich in dietary cholesterol, but low in saturated fat, will lead to increased risk of cardiovascular disease<sup>9,27,29,31</sup>.

The lack of evidence demonstrating an association between dietary cholesterol and increased heart disease risk, and the evidence now existing, although limited, concluding increased egg consumption, up to one - two eggs per day does no harm, has driven why most countries now do not recommend restricting cholesterol intake.. In particular, dietary guidelines from around the world have been revised with a more positive view on egg intake. The most recent AHA dietary guidelines<sup>65</sup> revised their recommendations on egg intake, removing any specific restrictions on their consumption and instead focusing generally on foods high in saturated fat and cholesterol. There still remains a guideline for cholesterol intake, with a recommended intake of 300mg/day for healthy individuals and 200mg for those with elevated cholesterol levels or CVD, which they state is achievable, and could include seven eggs a week if no other dietary cholesterol is consumed. In addition, there had been a shift in the AHA dietary guidelines to be more centered on the selection of healthy foods.

The recent update to the New Zealand Heart Foundation's healthy heart food guidelines<sup>66</sup>, does not include any specific restrictions on egg consumption for otherwise healthy individuals, and like the AHA dietary guidelines, look at the totality of the diet and a balanced inclusion of healthy foods. There still remains a recommendation that egg consumption should be limited to three a week if an individual is at high risk of heart disease<sup>13</sup>. New Zealand's Food and Nutrition Guidelines for healthy adults, developed in 2003, applied no limits on egg consumption, and have included eggs as part of an everyday balanced diet<sup>67</sup>.

Leading health organisations in the United Kingdom, National Health Service (NHS)<sup>68</sup> and the British Heart Foundation (BHF)<sup>69</sup>, both state eggs can be a part of a healthy balanced diet, and have included no restrictions on the amount of eggs consumed in their dietary recommendations.

Again, no specific intake recommendations are given for eggs in the Australian Dietary guidelines which were reviewed in 2013, and in fact they state there is no reason eggs cannot be consumed every day as part of a healthy diet<sup>70</sup>. The AHF released a position statement in 2009 on cardiovascular health including a recommendation that six eggs can be consumed per week as part of a heart healthy diet low in saturated fat<sup>71</sup>. In more recent 2012 guidelines released by the AHF on the management of heart disease risk, eggs were stated as a food to be included in an overall diet to manage and/or reduce the risk of heart disease, and no specific recommendation made to reduce dietary cholesterol intake<sup>72</sup>. Lastly, AHF has developed recommendations specifically related to egg consumption for people with diabetes, or those suffering from metabolic syndrome. These state that those with diabetes or metabolic syndrome, can consume up to six eggs each week alongside a heart healthy diet low in saturated fat, and they will not increase their risk of cardiovascular disease<sup>76</sup>.

As established, the increased research carried out demonstrating a positive association between eggs and cardiovascular disease risk has led to a shift in intake recommendations around the world. As more data becomes available from future controlled trials and interventions, it is predicted that we may see even further shift in recommendation rates for egg consumption in populations.

### ACTUAL EGG CONSUMPTION LEVELS

There is not a lot of specific data available for egg intake within the New Zealand population. The International Egg Commission (IEC) carries out market review in their member countries (34 countries), their statistics from 2008 states the average New Zealander consumes 225 eggs per year approximately four eggs per week, and a 3% increase from their 2007 market review. Their market review also shows New Zealand in the top 10 of egg consumers, even though we have the 3<sup>rd</sup> smallest population size in the review. We are therefore the 2nd top consumer of eggs according to population size<sup>73</sup>.

## DISCUSSION

The objective of this position paper is to provide an overview of the research available on eggs, their nutritional benefits and issues related to consumption, in order to form recommendations. A thorough and structured methodology has ensured relevant research to be identified and evaluated to meet this objective.

Public health messaging on eggs, their nutritional credentials and how they fit into the diet has evolved over the past decades<sup>5</sup>. Although an egg is a rich source in many essential nutrients, it is the cholesterol content of the food that has been given the most attention. This is partly due to earlier epidemiological data that demonstrated a weak, positive association between dietary cholesterol and cardiovascular risk, and the fact that eggs are one of the richest sources of dietary cholesterol<sup>28</sup>.

As our understanding has progressed on how dietary cholesterol and serum cholesterol relate to our risk of cardiovascular disease, so too has our understanding of how eggs specifically as a food, can have a positive or negative affect on our diet. Research is now suggesting that although dietary cholesterol can increase the total serum cholesterol, it may not have an impact on cardiovascular risk and mortality<sup>9, 27, 29, 31</sup>. It is suggested in research included in the review, that with foods high in dietary cholesterol that have shown to increase cardiovascular risk, it is actually the saturated fat and trans fat content commonly found alongside dietary cholesterol in foods, that is actually increasing the risk<sup>24</sup>. This has been supported in the growing number of studies both observational and controlled trials, where the weight of evidence suggests that increased egg consumption has little or no association with increased serum cholesterol levels and increased risk of cardiovascular disease<sup>9, 18 – 24, 27, 29, 31</sup>.

This review also covered additional health benefits of eggs and issues related to increased consumption that have raised concern. Eggs are a highly nutritious food, and alongside the rich source of high quality protein, and over 11 essential vitamins and minerals that eggs contain, research is also showing eggs are a rich source of the nutrient choline<sup>53</sup> and that increased consumption of eggs increases the serum concentrations of the two carotenoids Lutein and Zeaxanthin<sup>20, 61-62</sup>. Choline, Lutein and Zeaxanthin have been shown to have a protective role with many diseases and health conditions such as neural development, cognitive function, macular degeneration, cardiovascular disease and some cancers. It has been suggested that one of the reasons eggs have shown no association with increased cardiovascular disease risk, despite their high dietary cholesterol content, is the carotenoid content of eggs. The high quality protein content of eggs has encouraged research on the benefits of eggs for weight management, in particular the influence on satiety. Although findings are positive for the link between egg consumption and increased satiety and resulting weight loss, further research is still warranted to confirm the benefits of eggs as a food choice for long-term weight management<sup>43-47</sup>.

One disease the literature review has indicated as a potential concern for increased egg consumption is diabetes. Numerous studies looking at the association between increased egg consumption and increased cardiovascular risk, observed that the lack of association was not the case for diabetic participants. Increased egg consumption in diabetic participants, increased cardiovascular risk versus non-diabetics<sup>9, 27, 31</sup>. Studies have also demonstrated a negative association between egg consumption and the risk of diabetes itself. Three observational studies and one case-controlled study were reviewed. Two of the observational

studies and the case controlled study concluded increased egg consumption increased the risk of diabetes<sup>34–36</sup>. However one of the observational studies reviewed concluded there was no association between increased egg consumption and diabetes risk<sup>37</sup>. The difference in results could be explained by one of the limitations of the Djousse et al study, with only limited egg intakes included, due to the data available in the cohort studied. This could suggest that with higher consumptions, similar to that seen in other studies, they may have seen a different result. It is important to note that the National Heart Foundation of Australia have recently updated guidelines on egg consumption for diabetics, and they are recommending up to six eggs per week can be consumed without any adverse effects on cardiovascular risk<sup>76</sup>. However, it is suggested further case controlled and intervention research is necessary to understand more what it is about increased egg consumption that responds negatively with diabetics and its link to increased cardiovascular disease.

The more recent research that has taken place on egg consumption has influenced public health messaging on recommendations for egg consumption around the world. Dietary recommendations from the 1960's and 1970's restricted egg intakes, as part of their dietary recommendations for cardiovascular health<sup>5</sup>. However, these have evolved in more recent years with many health organisations reviewing their recommendations for egg intake. The AHA and AHF have reviewed their dietary recommendations for eggs, with the AHA removing any specific restrictions on eggs but retaining guidelines on cholesterol intake, and the AHF now recommending up to six eggs per weeks can be consumed as part of a heart healthy diet low in saturated fat. In New Zealand, the Heart Foundation does not recommend restricting egg intake for the general population, but continues to recommend limiting eggs to three per week for people at very high risk of heart disease; and this position is under review.<sup>13</sup>. However, the recent update of their healthy heart food guidelines include no specific restrictions on egg consumption, as do the New Zealand Food and Nutrition Guidelines<sup>66</sup>.

## STRENGTHS AND WEAKNESSES

The review comprised of observational studies from large prospective cohorts, some randomized controlled trials (RCT), meta-analysis and systematic reviews. The main strength of this literature review is the quality of data available. In particular, the observational studies were from extremely large, well-researched cohorts with sample sizes from 912 to 90,735 participants. These large sample sizes increase the authority of a study and the strength of evidence provided from this<sup>74</sup>. The long duration of follow up of these observational studies, significantly increased the statistical power to detect potential associations.

An additional strength of the observational studies is they took into account other influencing factors including, but not limited to high blood pressure and high cholesterol, BMI, age, diabetes and saturated fat intake. This meant there was a more accurate view on how egg consumption related to specific health issues. Another strength of this review is the amount of RCT's included. In total there were 25 RCT reviewed which gives the highest level of evidence on egg consumption and possible adverse health outcomes. Lastly, the consistent observations and conclusions made in the observational studies, then supported by the RCT's results is also a strength.

Conversely there are several limitations identified in this review. Much of our evidence is from observational studies, where the cohorts collected data via food frequency

questionnaires, whereby misreporting of intake must be considered and inevitable<sup>75</sup>. In addition, the cooking methods used in the consumption of eggs was not always available, which could significantly alter the nutritional composition of the egg meal, depending on the amount of fat and salt used in cooking and the size of the eggs consumed. Another limitation due to the use of observational studies in this review is although the long duration of the following in the cohorts increases the statistical power, it also could mean that participants have an opportunity to change their diets. Lastly, an overall limitation is that the diseases and health conditions we are discussing in this review, such as cardiovascular disease, diabetes and weight management are incredibly complex and their prevalence and development is highly dependent on a variety of lifestyle and genetic factors, and it would be hard to single out eggs and their effects on these types of diseases. However, this was considered in many of the observational studies where results were stratified against baseline results and various subgroup analyses conducted.

## RECOMMENDATIONS

### MICRO-LEVEL - DIETARY ADVICE

Due to the strength of evidence now available supporting the nutritional credentials of eggs and demonstrating the lack of association between increased egg consumption and cardiovascular risk, it is recommended that eggs should be considered a healthy food choice as part of balanced diet. As there are currently no restrictions place on egg consumption in otherwise healthy individuals in both the New Zealand Food and Nutrition Guidelines or by the Heart Foundation, this review of research can support a recommendation of up to one-two eggs per day as part of a heart healthy diet low in saturated fat for individuals not at risk for diabetes. However, it should be noted that New Zealanders do not typically have a diet low in saturated fat<sup>6</sup>.

However, if an individual wants to follow dietary guidelines that give a specific recommendation on egg intake, a suggestion would be to utilize the Australian NHF recommendations of up to six eggs per week as a guide.

### MESO-LEVEL - HEALTHCARE PROFESSIONALS

The evidence presented in this review suggests healthcare professionals should not be giving dietary advice to restrict egg consumption, even with patients that have high cholesterol or are at risk of cardiovascular disease. However research is limited and inconsistent, and in many cases not positive of egg consumption's association with risk of diabetes, and risk of cardiovascular disease in diabetic participants. However, as much of this research is observational, it would be suggested that healthcare professionals use the latest AHF recommendations for egg consumption with diabetics as their guide.

### MACRO-LEVEL - FOOD INDUSTRY

As a result of this literature review, it is concluded there is a lot of positive messages that could be communicated to the public on egg consumption and their nutritional credentials. Even though there has been a shift in leading health organisations' recommendations of egg intakes in several countries, within the New Zealand context there hasn't been such a formal change. Therefore, it could be that the average consumer's understanding of current recommendations for egg intakes and their nutritional credentials are low. Therefore there is an opportunity for the food industry to further research their consumer's understanding and knowledge on egg consumption and to increase the awareness of egg as a healthy food choice.

### MACRO-LEVEL - GOVERNMENT

There is an opportunity in the next revision of the Food and Nutrition Guidelines, to include more specific information on egg consumption, supported by the scientific evidence now available that promotes egg consumption as discussed in this review. There is currently no research available to confirm, but it is assumed that there is a significant amount of confusion amongst the general public on the nutrition credentials of eggs and exactly how many eggs can be consumed per day. Updated formal guidelines available from a New Zealand health authority, specifically on eggs, may provide the clarification that is needed for the general public to make informed decisions on their food choices.

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