



Summary of evidence

Dietary fats and dietary cholesterol for cardiovascular health

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1. Rationale and objectives

Rationale

Cardiovascular disease (CVD) refers to all diseases and conditions of the heart and blood vessels. The main types include coronary (or *ischaemic*) heart disease, stroke, heart failure, peripheral vascular disease, rheumatic heart disease and congenital heart diseases.

Coronary heart disease (CHD) is the most prevalent and serious form of CVD. CHD is manifested as angina, myocardial infarction (MI) and sudden death.

There are several accepted modifiable risk factors for CVD, including hypertension, elevated serum cholesterol, obesity, poor nutrition, physical inactivity, tobacco smoking, alcohol consumption and excessive stress. Other risk factors include age, gender, triglycerides, homocysteine and lipoprotein a (Lp(a)).

Aims and objectives

To ensure that the Heart Foundation recommendations were based on the best available evidence, this paper sought to collect and analyse the highest quality international studies, reviews and reports relating to dietary fats, dietary cholesterol, cardiovascular health (CVH) and CVD.

The objective of this summary of evidence was to synthesise new evidence where it related to:

- the relationships between CVD events (death from CHD, MI, sudden death) and individual fatty acids (FA), FA classes, total fat and dietary cholesterol
- the relationship between CVD risk factors (abnormal lipid profile, atherosclerosis, metabolic syndrome, diabetes) and individual FA, FA classes, total fat and dietary cholesterol
- the role of individual FA, FA classes, total fat and dietary cholesterol in CVH
- the evidence around the consumption of core foods high in total fat or dietary cholesterol
- effective dietary fat modifications in acute and GP settings
- gaps in research and practice.

Methodology

A traditional literature review was not performed. Instead, this summary of evidence built on the work of the previous dietary fats review by the Heart Foundation in 1999, as well as the review by Health Canada in 2000. Relevant meta-analyses, reviews and reports published since that time were considered. The literature search aimed to identify:

1. systematic reviews and meta-analyses published since 1999
2. major reports and critical reviews discussing dietary fats and CVD/CVH
3. existing international dietary guidelines and position statements in the area of dietary fats and CVD/CVH.

Computer-assisted literature searches were conducted using PubMed to locate literature published from 2000 to 2008, inclusive. Search terms included words, such as 'dietary', 'coronary', 'fatty', 'cardiovascular' and 'cholesterol'. Typical exclusion criteria included articles published before 2000 and reviews of drug trials. In addition, evidence was identified by checking the citations of key reviews, journal articles and articles related to the topic. The year range covered was determined by the date of the last Heart Foundation review. Some searches were expanded if results from the initial research were meagre.

In addition, a search for existing reports was conducted on Google using key words, such as 'fats', 'dietary fat and report', 'position statement and fat' and 'scientific statement and fat'. Websites of other local and international organisations that have reviewed the evidence around dietary fats and CVD/CVH were searched. These included the National Health and Medical Research Council (NHMRC), Food Standards Australia New Zealand (FSANZ), Health Canada, Scientific Advisory Committee on Nutrition, Food Standards Agency, American Heart Association and the World Health Organization (WHO). Unpublished reports were not excluded.

If a review was assessed as being poor quality (no conclusive findings, no clear objective), then it was excluded.

The literature search found many guidelines, research reports, meta-analyses and systematic reviews that focused on dietary FA and their relationship to CVH and CVD. These were summarised to produce a new evidence review paper.

NHMRC levels of evidence (Table 1) were attributed to the recommendations where appropriate, and the associated studies were listed. Where a level of evidence was not attributed, the evidence was obtained from documents and reports of recognised national and international authorities, where systematic reviews of the literature may not necessarily have been conducted. Where this is the case, a level of evidence is not appropriate (–). Where there is insufficient, inconclusive or conflicting evidence, the level of evidence is not applicable (n/a).

Table 1: NHMRC levels of evidence criteria

Study design	Level of evidence
Evidence obtained from a systematic review of all relevant randomised controlled trials	I
Evidence obtained from at least one properly designed randomised controlled trial	II
Evidence obtained from well-designed pseudo-randomised controlled trials (alternate allocation or some other method)	III-1
Evidence obtained from comparative studies with concurrent controls and non-randomised allocation, cohort studies, case-control studies or interrupted time series with a control group	III-2
Evidence obtained from comparative studies with historical control, two or more single-arm studies or interrupted time series without a parallel control group	III-3
Evidence obtained from case series, either post-test or pre-test and post-test data	IV

Source: *A guide to the development, implementation and evaluation of clinical practice guidelines*¹

2. Summary of evidence

These evidence statements are derived from the evidence presented in this paper. These statements update and supersede those developed in the previous position statement *A review of the relationship between dietary fat and cardiovascular disease*.² They also incorporate statements from two other Heart Foundation evidence papers: *Review of evidence. Fish, fish oils, n-3 polyunsaturated fatty acids and cardiovascular health*³ and *Summary of evidence on phytosterol/stanol enriched foods*.⁴

NHMRC levels of evidence were attributed to the recommendations where appropriate, and the associated studies were listed. Where there is insufficient, inconclusive or conflicting evidence, the level of evidence is not applicable (n/a). Little/moderate/good were the levels of evidence used in the Heart Foundation's previous position statement.²

Table 2: Summary of evidence

Evidence	Level of evidence
Saturated FA (SFA)	III-2
<ul style="list-style-type: none"> SFA intake is associated with CHD⁵ 	
<ul style="list-style-type: none"> Replacing SFA with <i>cis</i>-unsaturated FA has a greater positive influence on CHD risk than replacing SFA with carbohydrates (CHO)^{6,7} 	I
<ul style="list-style-type: none"> Replacing SFA with n-6 PUFA to achieve a ratio of PUFA to SFA of greater than one will reduce the risk of CHD (1999 evidence statement retained)² 	Good
<ul style="list-style-type: none"> Replacing SFA with monounsaturated FA (MUFA) lowers total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C), although not to the same extent as PUFA (1999 evidence statement retained)² 	Good
<ul style="list-style-type: none"> Increasing SFA intake results in an increase in TC and LDL-C compared to CHO, PUFA and MUFA (1999 evidence statement retained)² 	Good
<ul style="list-style-type: none"> Myristic, palmitic acids and lauric acids are associated with elevated LDL-C^{7,8} 	I
<ul style="list-style-type: none"> Stearic acid has a negligible effect on LDL-C^{7,8} 	I
<ul style="list-style-type: none"> Lauric, myristic and palmitic acids are associated with an increase in HDL-C compared to CHO. Lauric acid increase of high-density lipoprotein cholesterol (HDL-C) is greater than other individual SFA^{7,8} 	I
<ul style="list-style-type: none"> Lowering dietary SFA to <7% of energy intake with restricted dietary cholesterol results in further LDL-C lowering than diets containing <10% of energy intake from SFA⁹ 	II
<ul style="list-style-type: none"> There is little evidence that an increase in the consumption of SFA increases the incidence of stroke (1999 evidence statement retained)² 	Little
<ul style="list-style-type: none"> There is little evidence that an increase in the consumption of SFA affects the susceptibility to thrombosis and arrhythmia or blood pressure (1999 evidence statement retained)² 	Little

Evidence	Level of evidence
Trans FA (tFA)	II
<ul style="list-style-type: none"> tFA intake increases LDL-C, decreases HDL-C, increases Lp(a) and increases the concentration of fasting serum triglycerides (TG)^{5,10-12} 	
<ul style="list-style-type: none"> The use of FA in tissue as a marker of tFA has yielded conflicting results⁵ 	n/a
<ul style="list-style-type: none"> tFA intake is associated with increased CHD incidence and risk of CHD^{5,6,11,13,14} 	III-2
<ul style="list-style-type: none"> tFA intake is associated with an increased risk of non-fatal and fatal MI^{5,14,15} 	III-2
<ul style="list-style-type: none"> tFA intake has little effect on haemostatic factors, the susceptibility of LDL-C to oxidation, or blood pressure, but may have an adverse effect on postprandial lipids and endothelial function^{11,16} 	II
<ul style="list-style-type: none"> Ruminant tFA have a similar effect on LDL-C and HDL-C as industrially produced tFA^{15,17-19} 	II
<ul style="list-style-type: none"> Replacing partially hydrogenated oils (PHO) with oils high in <i>cis</i>-unsaturated FA improves the lipid profile^{7,20,21} 	I
n-6 PUFA	II
<ul style="list-style-type: none"> n-6 PUFA intake lowers LDL-C²² 	
<ul style="list-style-type: none"> It is unclear whether lowering the n-6 PUFA:n-3 PUFA ratio is beneficial for CVH²³⁻²⁶ 	n/a
<ul style="list-style-type: none"> The CVH benefits of n-3 PUFA are not influenced by background n-6 PUFA^{27,28} 	III-2
<ul style="list-style-type: none"> There is little evidence that an increase in the consumption of n-6 PUFA affects the susceptibility to thrombosis and arrhythmia or blood pressure (1999 evidence statement retained)² 	Little
n-3 PUFA (all from <i>Fish, fish oils, n-3 polyunsaturated fatty acids and cardiovascular health</i>²⁹)	II
<ul style="list-style-type: none"> In secondary prevention, a diet with 2 g/day of ALA decreases the risk of CHD³⁰⁻³² 	
<ul style="list-style-type: none"> In secondary prevention ≥ 850 mg/day marine n-3 PUFA supplementation reduces the risk of CHD mortality, and $\geq 1,800$ mg/day reduces major coronary events³³⁻³⁵ 	II
<ul style="list-style-type: none"> In secondary prevention, there is conflicting evidence about the effect of marine n-3 PUFA supplementation on the risk of sudden death in patients^{33,36-40} 	II
<ul style="list-style-type: none"> Marine n-3 PUFA supplementation of 1,000–4,000 mg/day decreases TG levels by 25–30% and increases HDL-C levels by 1–3%. A dose relationship exists between the intake of marine n-3 PUFA and decreased TG levels⁴¹⁻⁴³ 	I
<ul style="list-style-type: none"> Marine n-3 PUFA has an additive effect to statin therapy in decreasing TG levels and increasing HDL-C⁴⁴⁻⁵⁰ 	II

Evidence	Level of evidence
MUFA <ul style="list-style-type: none"> There is little evidence that MUFA have an independent effect on coronary endpoints (1999 evidence statement retained)² 	Little
<ul style="list-style-type: none"> There is little evidence that an increase in the consumption of MUFA affects the susceptibility to thrombosis and arrhythmia or blood pressure (1999 evidence statement retained)² 	Little
Total fat <ul style="list-style-type: none"> There is no direct relationship between total fat intake and the incidence of CHD⁶ 	n/a
<ul style="list-style-type: none"> An increase in the consumption of SFA and tFA, rather than total fat, increases the risk of CHD (1999 evidence statement retained)² 	Good
Dietary cholesterol <ul style="list-style-type: none"> There is inconclusive evidence supporting a relationship between dietary cholesterol and CVD outcomes²² 	n/a
<ul style="list-style-type: none"> There is little evidence of a relationship between serum cholesterol and stroke⁵¹ 	III-2
<ul style="list-style-type: none"> Dietary cholesterol increases TC and LDL-C, but substantially less so than SFA and tFA (1999 evidence statement retained)² 	Moderate
HDL-C and TC:HDL-C <ul style="list-style-type: none"> Higher HDL-C may reduce the risk of CHD⁵¹ 	III-2
<ul style="list-style-type: none"> TC:HDL-C is an informative predictor of CHD mortality⁵² 	III-2
Specific foods <ul style="list-style-type: none"> Consuming up to six eggs/week in a diet low in SFA is not associated with adverse CVD outcomes. Increased egg consumption may increase CHD risk in people with diabetes⁵³⁻⁶⁰ 	III-2
<ul style="list-style-type: none"> Individuals with a higher intake of fish have a lower risk of CHD mortality, total CHD and total stroke⁶¹⁻⁶³ (from <i>Fish, fish oils, n-3 polyunsaturated fatty acids and cardiovascular health</i>²⁹) 	III-2
<ul style="list-style-type: none"> Consuming fish at least once a week is associated with a lower risk of total stroke and CHD mortality in the general population and post-MI patients⁶¹⁻⁶⁵ (from <i>Fish, fish oils, n-3 polyunsaturated fatty acids and cardiovascular health</i>²⁹) 	III-2
<ul style="list-style-type: none"> Consuming nuts improves the lipid profile^{66,67} 	I
Dietary modifications <ul style="list-style-type: none"> Dietary changes longer than two years can reduce cardiovascular events and total mortality among high-risk patients⁶⁸ 	I
Phytosterol/stanols (all from <i>Summary of evidence on phytosterol/stanol enriched foods</i>) <ul style="list-style-type: none"> Phytosterols lower LDL-C in normocholesterolaemic, hypercholesterolaemic and diabetic individuals⁶⁹ 	I

Evidence	Level of evidence
<ul style="list-style-type: none"> For people with an increased risk of CVD, consuming phytosterol/stanol enriched foods provide an additional option for risk reduction through lowering the level of cholesterol^{70,71} 	II
<ul style="list-style-type: none"> A daily intake of approximately 2 g of phytosterol/stanol enriched margarine reduces LDL-C levels by approximately 10%, but has little effect on HDL-C or triglycerides (TG)^{72,73} 	I
<ul style="list-style-type: none"> A daily intake of approximately 2.5 g phytosterol enriched low-fat breakfast cereal, yoghurt, milk or bread reduces LDL-C levels by approximately 5–15%⁷⁴⁻⁷⁶ 	II
<ul style="list-style-type: none"> Consuming phytosterol/stanol enriched foods at levels higher than 2–3 g/day provides no additional benefits to lowering LDL-C^{77,78} 	I
<ul style="list-style-type: none"> Daily consumption frequency does not influence the cholesterol-lowering efficacy of phytosterol/stanols^{72,79,80} 	II
<ul style="list-style-type: none"> Phytosterol/stanol enriched foods have an additive effect in lowering LDL-C when combined with statins⁸¹⁻⁸⁷ 	II
<ul style="list-style-type: none"> There are no reported adverse effects from the daily consumption of phytosterol/stanol enriched foods, although long-term safety information is not available^{77,88-97} 	II
<ul style="list-style-type: none"> When consuming phytosterol/stanol enriched foods, blood carotenoids are reduced. An additional serving of high-carotenoid fruit and vegetables is effective in maintaining blood carotenoid concentrations^{73,93,95,98-101} 	II
<ul style="list-style-type: none"> Individuals with the rare inherited metabolic disease, homozygous sitosterolaemia, have high blood phytosterol levels and premature atherosclerosis. A restricted intake of phytosterols is recommended for these individuals¹⁰² 	II

3. The effect of new evidence on evidence presented in *A review of the relationship between dietary fat and cardiovascular disease (1999)*

Using the evidence presented in this paper (Table 2) and *Fish, fish oil, n-3 polyunsaturated fatty acids and cardiovascular health*,³ the evidence from *A review of the relationship between dietary fat and cardiovascular disease*² is updated as follows:

- **same** – no new evidence found, evidence statements are still relevant
- **updated** – 1999 evidence confirmed by new evidence, evidence statement updated
- **replace** – 1999 evidence replaced by new evidence
- **fish** – *Review of evidence. Fish, fish oils, n-3 polyunsaturated fatty acids and cardiovascular health*.³

Table 3: Summary of evidence from Heart Foundation's 1999 dietary fat paper and its status in relation to new evidence

1999 evidence statements	Status in relation to 2008 evidence papers
SFA	
There is good evidence that:	
• an increase in the consumption of SFA is associated with an increase in risk of CHD	Updated
• replacing a proportion of SFA with n-6 PUFA to achieve a ratio of PUFA to SFA of greater than 1 will reduce the risk of CHD	Same
• compared to CHO, PUFA and MUFA, an increase in the consumption of SFA results in an increase in the concentration of TC and LDL-C, and	Updated
• replacing SFA with CHO, PUFA or MUFA lowers TC and LDL-C, with a slightly greater effect with PUFA	Replace
There is little evidence that:	
• an increase in the consumption of SFA increases the incidence of stroke, and	Same
• an increase in the consumption of SFA increases or decreases susceptibility to thrombosis and arrhythmia or increases or decreases blood pressure	Same
tFA	
There is good evidence that:	
• compared to PUFA and MUFA, tFA increase the concentration of TC and LDL-C, and lowers HDL-C	Updated
There is moderate evidence that:	

1999 evidence statements	Status in relation to 2008 evidence papers
<ul style="list-style-type: none"> tFA increase the risk of CHD, particularly at high levels of intake 	Updated
n-6 PUFA	
There is good evidence that:	
<ul style="list-style-type: none"> replacing SFA with n-6 PUFA reduces the risk of coronary events and deaths, and 	Same
<ul style="list-style-type: none"> replacing SFA with n-6 PUFA lowers the concentration of LDL-C, TC and TG 	Same
There is little evidence that:	
<ul style="list-style-type: none"> an increase in the consumption of n-6 PUFA increases or decreases susceptibility to thrombosis and arrhythmia or increases or decreases blood pressure 	Same
n-3 PUFA	
There is good evidence that:	
<ul style="list-style-type: none"> marine n-3 PUFA reduce coronary heart events 	Fish
<ul style="list-style-type: none"> fish intake reduces the risk of coronary death 	Fish
<ul style="list-style-type: none"> marine n-3 PUFA prevent arrhythmia in animals, and 	Fish
<ul style="list-style-type: none"> marine n-3 PUFA reduce the concentration of TG 	Fish
There is moderate evidence that:	
<ul style="list-style-type: none"> marine n-3 PUFA prevent arrhythmia in humans, and 	Fish
<ul style="list-style-type: none"> ALA intake reduces the risk of coronary endpoints 	Fish
There is little evidence that:	
<ul style="list-style-type: none"> the anti-thrombotic effect of n-3 PUFA has any impact on coronary endpoints 	Fish
MUFA	
There is good evidence that:	
<ul style="list-style-type: none"> replacing SFA with MUFA lowers TC and LDL-C, although not to the same extent as PUFA 	Same
There is little evidence that:	
<ul style="list-style-type: none"> MUFA have an independent effect on coronary endpoints, and 	Same

1999 evidence statements	Status in relation to 2008 evidence papers
<ul style="list-style-type: none"> an increase in the consumption of MUFA increases or decreases susceptibility to thrombosis and arrhythmia or increases or decreases blood pressure 	Same
Dietary cholesterol	
There is moderate evidence that:	
<ul style="list-style-type: none"> dietary cholesterol increases TC and LDL-C, but substantially less so than SFA and tFA, and 	Same
<ul style="list-style-type: none"> dietary cholesterol contributes to the development of CHD 	Same
Total fat	
There is good evidence that:	
<ul style="list-style-type: none"> an increase in the consumption of SFA and tFA, rather than total fat, increases the risk of CHD 	Same

4. Dietary fats, dietary cholesterol and CVH

This section will first outline the knowledge that was established at the time of the Heart Foundation's *Review of the relationship between dietary fat and cardiovascular disease*.² The second part will then bring together the new evidence that has arisen since 1999 for each of the dietary fat and cholesterol components.

Established knowledge (current paradigm)

Low plasma levels of HDL-C and high plasma levels of LDL-C and TG are recognised as risk factors for CVD. Modifying plasma lipid levels through diet is one way to reduce the risk of CVD.

FA classes

It has been well established that the consumption of SFA increases TC, HDL-C and LDL-C, even at low levels.^{2,103} Evidence for a dose–response relationship between SFA and LDL-C exists,¹⁶ and meta-analyses have demonstrated that for each 1% increase in energy from SFA, serum LDL-C increases by about 2%; for every 1% decrease in energy from SFA, serum LDL-C decreases by about 2%.^{104,105} The consumption of SFA and increased LDL-C levels are associated with an increase in CHD,^{2,24} although the strength of this association has recently been questioned.⁵ The Heart Foundation paper *A review of the relationship between dietary fat and cardiovascular disease*² found good evidence that replacing SFA with n-6 PUFA reduced the risk of CHD, and that replacing SFA with any PUFA, MUFA or CHO would decrease LDL-C levels.

The consumption of tFA results in increased plasma LDL-C, and relative to SFA, lower HDL-C and increased Lp(a). These changes in the lipid profile suggest that it is a greater risk factor for CHD than SFA.¹⁰³

Total fat

It is generally accepted that a reduction in total fat will not lower plasma cholesterol or lipoprotein levels and does not have a beneficial effect on CHD or CHD risk factors, independent of its effect on lowering SFA.¹⁰³ Internationally, emphasis has shifted away from total fat intake towards FA classes. The Heart Foundation paper *A review of the relationship between dietary fat and cardiovascular disease*² concluded that emphasis should be placed on reducing the consumption of SFA and tFA rather than total fat.

Cholesterol

The Health Canada report from 2000¹⁰³ stated that dietary cholesterol was not a major factor influencing plasma LDL-C and lipoprotein levels. Revised estimates in the report stated that a decrease of 100 mg dietary cholesterol resulted in a decrease in plasma cholesterol of only 0.05 mmol/L. The report suggested that only people identified with high levels of plasma cholesterol needed to restrict their intake of cholesterol-rich foods.

CVD and lipid profiles—new and emerging evidence

FA classes

a. SFA

- Replacing SFA with *cis*-unsaturated FA (MUFA or PUFA) may have a greater positive influence on CHD risk than replacing SFA with CHO.
- Myristic, palmitic and lauric acids are associated with elevated LDL-C.
- Stearic acid has a negligible effect on LDL-C.
- Lauric, myristic and palmitic acids are associated with an increase in HDL-C compared to CHO. Lauric acid increase of HDL-C is greater than other individual SFA.^{7,8}
- Lowering dietary SFA to <7% of energy intake with restricted dietary cholesterol results in further LDL-C lowering than diets containing <10% of energy intake from SFA.

Discussions of SFA and CVD were identified in a number of recent reviews.

A 2005 report undertaken for FSANZ comprehensively reviewed the literature on SFA, tFA, LDL-C and CHD.⁵ The review summarised the findings from prospective studies published since 2000. The authors found a large pool of data to support the finding that a reduction in SFA intake, even in childhood, has the potential to reduce LDL-C levels. No new prospective studies were found, but further analyses were reviewed. The authors concluded that despite inconsistent findings supporting a positive association between SFA intake and CHD, the conclusion was that ‘the association is “probably” causal rather than “convincingly” causal’.

A meta-analysis of 60 studies⁷ evaluated the effects of dietary FA on the lipid profile. The authors concluded that ‘total:HDL cholesterol is more sensitive and specific than is total cholesterol as a risk predictor’ and emphasised the possible difficulty of relying on cholesterol alone as a marker of CHD risk. This meta-analysis and others^{7,8,104} highlighted the differential effects of individual SFA in changing the lipid profile and found:

- myristic and palmitic acids are associated with elevated LDL-C
- stearic acid has a negligible effect on LDL-C
- lauric acid has the most potent effect on LDL-C, but intake is low in most populations
- lauric, myristic and palmitic acids are associated with an increase in HDL-C compared to CHO
- lauric acid was the only individual SFA predicted to decrease TC:HDL-C relative to CHO.

In a review by Mozaffarian,⁶ the author concluded that there is stronger evidence for replacing SFA with *cis*-unsaturated FA to reduce CHD risk than for replacing SFA with CHO to reduce CHD risk. The Mensink meta-analysis⁷ also found that replacing SFA with *cis*-unsaturated FA decreased the TC:HDL-C ratio and CHD risk, and replacing SFA

with CHO did not improve the TC:HDL-C ratio. The Nurses Health Study¹⁰⁶ demonstrated that the replacement of 5% of energy from SFA with MUFA is associated with a 37% lower risk of CVD. Whether replacing SFA with MUFA or PUFA is more beneficial for CHD needs further research as current support for MUFA as a substitute comes largely from epidemiological data and risk factor analyses.¹⁰⁷

In 2002, a review and update of US dietary reference values was undertaken by the National Academy of Sciences' Institute of Medicine (IOM).¹⁶ The recommendation to decrease SFA as much as possible while consuming a nutritionally adequate diet was supported by evidence from a systematic review of 27 controlled trials. The IOM decided that SFA have no known role in preventing chronic disease, so no minimum intake value was set. No upper limit value was set since any incremental increase in SFA intake increases CHD risk. The report noted that SFA are found in whole-foods, and eliminating them from the diet is not possible or advisable. The report recommended that adults with LDL-C <130 mg/dL (3.3 mmol/L) consume a diet with <10% SFA, and those with LDL-C ≥130 mg/dL consume <7% SFA. While the Australian recommendations suggest a limit of 8–10% of energy from SFA and tFA combined,²⁴ recent trials have found that lowering dietary SFA to <7% of energy with restricted dietary cholesterol results in further LDL-C lowering than diets containing <10% of energy from SFA.⁹ Recommendations to reduce SFA to <7% of energy are now widespread.^{108,109}

b. tFA

- tFA intake increases LDL-C, decreases HDL-C, increases Lp(a) and increases fasting TG.
- The use of FA in tissue as a marker of tFA have yielded conflicting results.
- tFA intake is associated with increased CHD incidence and the risk of CHD.
- tFA intake is associated with an increased risk of non-fatal or fatal MI.
- tFA intake has little effect on haemostatic factors, the susceptibility of LDL-C to oxidation, or blood pressure, but may have an adverse effect on postprandial lipids and endothelial function.
- Ruminant tFA has a similar effect on LDL-C and HDL-C as industrially produced tFA.
- Replacing PHO with oils high in *cis*-unsaturated FA improves the lipid profile.

Numerous dietary intervention and metabolic studies have confirmed that tFA intake increases LDL-C, decreases HDL-C and raises fasting TG.^{5,10,11} There is no definitive answer as to whether the effect of tFA on LDL-C is different to SFA on a gram-for-gram basis. Elevated Lp(a) is related to an increased risk for CVD. SFA lowers blood Lp(a), while tFA raise Lp(a). A review of studies of the effects of tFA on Lp(a) concluded that for people with normal Lp(a) concentrations, increases would not have a significant impact on cardiovascular risk.¹¹ Individuals with elevated Lp(a) might benefit from reducing their intake of tFA.

Results from case control studies exploring the association between adipose tissue tFA, tFA intake and sudden cardiac death have been inconsistent.⁵

Several prospective cohort and case control studies support an association between the intake of tFA and CHD incidence,¹³ and the intake of tFA and risk of CHD,^{6,11,14,15} while Booker and Mann have found the data to be heterogeneous and concluded that the association between tFA and CHD is 'probable' rather than 'convincing'.

Case-control studies have demonstrated an association between tFA intake and the risk of non-fatal or fatal MI.^{5,14} A study of an Australian population consuming tFA in margarine (before tFA were removed from the major margarines) found that the most abundant isomer *t*18:1 was an independent predictor of first MI.¹⁵

The 2002 IOM report¹⁶ stated that tFA are non-essential and provide no nutritional value, therefore no minimum intake levels were set. The report did not set upper limits because any intake increases CHD risk. The report stated that the consumption of tFA in a non-vegan diet is unavoidable, and eliminating them from the diet would require significant changes in patterns of dietary intake and found that such adjustments may increase health risks by eliminating core foods. The report recommended that 'trans FA consumption be as low as possible while consuming a nutritionally adequate diet'. The data from the report indicated that tFA have little effect on haemostatic factors and susceptibility of LDL-C to oxidation, while clinical studies have reported that tFA have an adverse effect on postprandial lipids¹¹⁰ and endothelial function.¹¹¹ Human intervention studies did not provide any evidence that tFA affect blood pressure.^{11,16}

A meta-analysis⁷ highlighted the importance of the source of tFA, since intake of ruminant tFA from milk and cheese were less consistently associated with CHD than industrially produced tFA. However, findings were not consistent and the authors recommended that the intake of ruminant tFA be kept low by choosing skimmed dairy products and lean meat. While the majority of evidence suggests a relationship between the intake of industrially produced tFA and CHD, one study found both vegetable *and* ruminant tFA contributed to the increased risk,¹⁵ and further evidence suggested that the risk of CHD was similar for intakes up to 2 g/day.¹⁷ The TRANSFACT study^{112,113} compared ruminant and industrially produced tFA at ≈5% of energy. The results suggested that dairy and industrially produced tFA have different effects on LDL-C, HDL-C and TG in women, but not men, and HDL-C was lowered only by industrially produced tFA. Another short-term randomised controlled trial of three tFA diets (3.7%, 1.5% and 0.8% of energy) found no difference in the effect of ruminant or industrially produced tFA on LDL-C and HDL-C at the highest level.¹⁸ Significantly different effects on blood lipids were seen between the diet with 1.5% of energy from ruminant tFA and the low-tFA diet (0.8% of energy). It is not known whether equal amounts of tFA from industrial and ruminant sources have a similar effect on blood lipids, but tFA from natural sources in (small) actual amounts do not greatly contribute to the risks of CHD, and the evidence does not support a beneficial effect.¹⁹

A 2006 report of the Trans Task Force for Health Canada reviewed the literature and made recommendations for reducing industrially produced tFA in the Canadian food supply.²⁰ Evidence suggested that replacing PHO with oils high in *cis*-MUFA would have a positive effect on the lipid profile and CHD risk. They found that at high levels of tFA intake (5.7–11.0% of total energy intake), the negative health impacts of tFA were greater than those of SFA (14–20% of total energy intake). It was agreed that butter and

other animal fats were not a good replacement for PHO, but some health effects could be achieved if tFA was replaced by SFA. The Task Force suggested that *cis*-MUFA be considered when choosing substitutes for tFA and SFA in food products. A meta-analysis concluded that the replacement of tFA with *cis*-MUFA or *cis*-PUFA is 'the single most effective measure for improving blood lipid profiles'.⁷ In contrast to some of the considerations of the Health Canada report, Noakes²¹ warned against substituting tFA at the expense of increasing SFA. The Health Canada experts agreed that evidence was sufficient to consider TC:HDL-C as a biomarker for assessing the effects of dietary fats on CHD. C-reactive protein (a non-lipid marker of inflammation) was found to be a stronger biomarker, but had less supporting evidence.

Alternatives for food manufacturers have been difficult to find because of the physical properties and chemical stability of tFA. Some articles^{7,114} have suggested palm oil as an acceptable alternative to tFA, but while favoured by manufacturers, palm oil has been found to elevate LDL-C and apolipoprotein B compared to canola or soybean oils.¹¹⁵ A US report¹⁴ discussed stearic acid as a substitute for tFA in prepared foods. Stearic acid offers the appropriate physical properties that a solid fat imparts, while having a neutral effect on serum TC and LDL-C concentrations. The neutral effect of stearic acid was confirmed by Thijssen and Mensink.^{7,116}

c. *Polyunsaturated FA*

- n-6 PUFA intake lowers LDL-C.
- It is unclear whether lowering the n6:n3 ratio is beneficial for CVH.
- The CVH benefits of n-3 PUFA are not influenced by background n-6 PUFA.

The CVH benefits of consuming n-3 PUFA are numerous and have been extensively reviewed in the *Review of evidence. Fish, fish oils, n-3 polyunsaturated fatty acids and cardiovascular health*.³ The effects of n-3 PUFA on CHD, MI, stroke, blood cholesterol, triglycerides, blood pressure, endothelial function, arterial compliance, heart rate, heart rate variability and atrial fibrillation, and in particular, the beneficial effects of n-3 PUFA for lowering TG were described.

The following evidence focuses on n-6 PUFA and CVH.

Evidence from six short-term intervention studies presented by the US IOM's report²² demonstrated that higher compared to lower n-6 PUFA intake decreased LDL-C. No adverse effects were reported even at the highest intakes. Sacks and Campos¹¹⁷ have stated that 'linoleic acid...remains the most effective PUFA for lowering serum cholesterol and the FA most well established to prevent CVD'.

A 2008 review²³ addressed the issue of whether the ratio of n-6:n-3 or total PUFA was more important to CVH. The author concluded that the n-6:n-3 ratio was of no value in modifying CHD risk and recommended an increase in consumption of n-3 PUFA (EPA, DHA and ALA) and decrease in linoleic acid. The NHMRC found inconsistent evidence of the benefit of lowering the n-6:n-3 ratio on CVH.²⁴ Others have found that both the absolute amount of n-3 PUFA and the n-6:n-3 ratio seem to be important for health.²⁵ A review by Lands²⁶ demonstrated that the imbalance between n-6 PUFA and n-3 PUFA

was associated with increasing CHD mortality (using trans-national epidemiology) and recommended the increased consumption of n-3 PUFA.

The Health Professionals Follow-up Study²⁷ found that EPA and DHA were inversely associated with tumour necrosis factor receptors 1 and 2. The findings suggested that n-6 PUFA did not inhibit the anti-inflammatory effects of n-3 PUFA, and that the combination of n-3 and n-6 PUFA were related to the lowest levels of inflammation. Similarly, others found that n-6 PUFA did not greatly reduce the CVH benefits of a modest intake of marine n-3 PUFA.²⁸

d. MUFA

There is not enough evidence at this time to make any new evidence statement.

MUFA have been receiving increased attention as being potentially beneficial for risk reduction because of their role in the Mediterranean diet and their use in replacing SFA and tFA. The main MUFA is oleic acid; olive, canola and peanut oils are all rich in oleic acid.

High-MUFA (17% and 21% MUFA from peanut oil and olive oil diets, respectively), low-SFA diets have been shown to lower TC by 10% and LDL-C by 14%, compared to the average American diet.¹¹⁸ The high-MUFA diet lowered TG concentrations by 13%, and HDL-C was not lowered. The olive oil diet was estimated to decrease CVD risk by 25%. Findings from the Heart Foundation's 1999 dietary fat position statement² in relation to the minimal effect of a moderate-MUFA diet and the greater effect of PUFA for lowering LDL-C, has not changed. This is confirmed in a recent randomised controlled trial by Binkoski *et al.*,¹¹⁹ who compared two diets with low SFA. The vegetable oil diet (MUFA 14.2%, PUFA 7.7%) decreased both LDL-C and TC compared to the olive oil diet (MUFA 17.2%, PUFA 4.3%). No adverse effects on LDL oxidation were observed. More research into the optimal balance of unsaturated FA, for replacing SFA and providing the greatest CVH benefits, is needed.

Recent epidemiological evidence from Mediterranean countries suggest that MUFA intake from olive oil is associated with lower blood pressure, and limited evidence suggests MUFA is associated with beneficial effects on coagulation factors, inflammation and endothelial activation.¹²⁰

The US IOM's 2005 report²² stated that 'monounsaturated fatty acids have no known independent role in preventing chronic diseases... Within the range of usual intake, there are no clearly established adverse effects of n-9 monounsaturated fatty acids in humans....' The IOM concluded that further studies are needed to evaluate CVD risk status and risk of other chronic diseases in individuals consuming a high MUFA diet versus a diet lower in MUFA (and higher in carbohydrate).

Total fat

There is no direct relationship between total fat intake and the incidence of CHD.

Evidence from prospective cohort studies and randomised controlled trials has not proven a positive relationship between total fat intake and the incidence of CHD with some evidence even suggesting that reducing total fat intake might increase CHD risk.⁶ Previous dietary recommendations to reduce total fat have little evidence to support them, and as such, American Heart Association and US Department of Agriculture guidelines have dropped the recommendation to maintain total fat below 30% of energy.¹²¹ In order to reduce chronic disease risk, the NHMRC²⁴ have recommended that total fat intake be 20–35% of energy.

Cholesterol

- There is inconclusive evidence supporting a relationship between dietary cholesterol and CVD outcomes.
- There is little evidence of a relationship between serum cholesterol and stroke.

Dietary cholesterol increases serum TC and LDL-C, but the impact is much less impressive than the impact from intake of SFA or tFA.¹²² Epidemiological data consistently show that dietary cholesterol has little effect on CHD incidence.^{56,123}

The US IOM's 2005 report²² reviewed the data for the association between dietary cholesterol and CVD. A review of 15 epidemiological studies found that six of those studies indicated a positive relationship between cholesterol intake and CVD and/or biomarkers of CHD. However, limited power from these studies led the authors to conclude that existing data did not convincingly establish the adverse health effects of dietary cholesterol. The report recommended that cholesterol intake be 'as low as possible while consuming a nutritionally adequate diet.'

Individual response to dietary cholesterol varies according to baseline serum cholesterol levels¹²⁴ with inter-individual variation in blood cholesterol response to dietary cholesterol ranging from 0 to greater than 100%. Approximately 15–25% of the population are hyper-responders to dietary cholesterol,¹²⁵ and responsiveness to dietary cholesterol highly correlates with responsiveness to dietary SFA.¹²⁶ Individuals with type 2 diabetes (T2DM) were found to have lower cholesterol absorption than individuals without T2DM.¹²⁷⁻¹²⁹ Insulin-resistant individuals seem to have a diminished response to dietary cholesterol compared with insulin-sensitive individuals.¹³⁰

Phytosterols are poorly absorbed into the gut, but compete with the uptake of the cholesterol.⁴ This means that the more phytosterols, the less dietary cholesterol may be absorbed. The cholesterol-lowering effect of phytosterol/stanol-enriched foods has been well documented, and systematic reviews studying the efficacy of phytosterols have shown that phytosterol/stanol-enriched foods can significantly lower LDL-C.

Australian and international public health recommendations for dietary cholesterol are summarised in Table 4.

Table 4: Australian and international population health dietary cholesterol recommendations

Country	Organisation	Cholesterol recommendations
Australia	NHMRC ²⁴	No cholesterol recommendations or upper limit. Focus on SFA and tFA intake
International	WHO ¹⁰⁸	Limit the population (average) intake of dietary cholesterol to <300 mg/day
US	IOM ¹⁴	<300 mg per day of dietary cholesterol should be consumed. Some individuals (with LDL-C ≥130 mg/dL) may benefit from <200 mg/day
US	American Diabetes Association ¹³¹	<300 mg per day of dietary cholesterol should be consumed. Some individuals (with LDL-C ≥100 mg/dL) may benefit from <200 mg/day
Canada	Health Canada ¹⁰³	No cholesterol recommendations or upper limit. Focus on SFA and tFA intake

Note: To convert mg/dL of HDL or LDL-C to mmol/L, divide by 39

Conjugated linoleic acid (CLA)

The evidence is not strong enough at this time to make any statement.

This lipid-based compound is commonly found in beef, lamb and dairy products and is proposed to have anti-atherogenic properties. The most abundant isomer of CLA in nature is c9t11, but commercially available CLA is usually a 1:1 mixture of c9t11 and t10c12. The health benefits of CLA have been mostly attributed to these two isomers.

Animal studies have consistently shown positive outcomes, while results in humans have been inconsistent, and differing methods between trials have made findings difficult to compare.¹³² CLA has been observed to decrease plasma TC and LDL-C with unchanged HDL-C and TG levels in healthy overweight subjects,¹³³ while another study showed no effect on serum LDL-C, HDL-C and TG.¹³⁴

While the effect of CLA is clear in animal models, the anti-atherosclerotic and lipid-lowering effects of CLA and individual isomers have not been adequately explored either *in vivo* or *in vitro*.¹³² Further long-term research is needed to elucidate the mechanisms of action and the efficacy in different populations of humans.

HDL-C and TC:HDL-C

- Higher HDL-C may reduce the risk of CHD.
- TC:HDL-C is an informative predictor of CHD mortality.

A large meta-analysis of observational studies found a positive relationship between serum TC and death from CHD across all ages and at all blood pressure levels.⁵² In addition, the ratio TC:HDL-C was found to be substantially more informative as a predictor of CHD mortality than TC, HDL-C or non-HDL-C.⁵² A meta-analysis of cohort studies found clear evidence that higher HDL-C is an advantage to the risk of CHD.⁵¹

A recent meta-analysis of cohort studies found some evidence that decreasing the TC:HDL-C ratio might have an adverse effect on haemorrhagic stroke, but not ischaemic stroke.⁵¹

CVH and specific foods

Eggs

Consuming up to six eggs/week in a diet low in SFA is not associated with adverse CVD outcomes. Increased egg consumption may increase CHD risk in people with diabetes.

Eggs contain a wide range of nutrients, including high-quality protein, folate, selenium, choline, n-3 PUFA, and antioxidants lutein and zeaxanthin. Because eggs contain on average 200 mg cholesterol, the effect of egg consumption on the risk of CHD has been strongly debated for a number of years. Currently, Australians consume about three eggs per week.¹³⁵

A meta-analysis of 17 human experimental studies showed that consuming one egg per day raised TC by 0.111 ± 0.010 mmol/L (4.3 ± 0.4 mg/dL), LDL-C by 0.100 ± 0.008 mmol/L (3.9 ± 0.3 mg/dL) and HDL-C by 0.016 mmol/L (0.6 ± 0.1 mg/dL), therefore increasing the risk of CHD.⁵³ Using these results, McNamara⁵⁵ predicted that the increase in risk of MI from consuming 3–4 eggs/week ranged from 0.5% to 1.5%. In addition, the meta-analysis by Weggemans *et al.*⁵³ divided the studies into two groups and found that when the diet was low in SFA, each 100 mg of added dietary cholesterol (half an egg/day) raised LDL-C by only 0.036 ± 0.004 mmol/L. Natoli *et al.*⁵⁷ described the effect of adding eggs to a diet low in SFA as 'clinically insignificant'.

Two reviews^{54,56} and a number of prospective and case control studies (Table 5) came to the conclusions that there is little evidence linking higher (>six/week) egg consumption and increased risk of CHD.

Another recent review on the role of eggs within a healthy diet⁵⁷ reviewed nine epidemiological studies and found no convincing evidence that increasing the consumption of eggs increases CVD risk.

In individuals with T2DM, evidence has shown an association between egg consumption and CHD risk⁵⁸ and egg consumption and increased risk of CHD⁵⁹ when more than six eggs per week are consumed. Although not a primary outcome, Trichopoulou *et al.* found that the increased consumption of egg and SFA was associated with increased diabetic mortality;⁶⁰ however, this study had very few cases and did not make adjustments for body mass index.

A study of Aboriginal Australians found that consuming more than two eggs per week was associated with increased risk of CHD, but egg consumption was also associated with high-risk behaviours, such as high levels of smoking.¹³⁶ More research describing the CVH risks and benefits of egg consumption in high-risk groups is needed.

Table 5: Prospective and case-control studies measuring CVD events and egg consumption

Study and number of subjects	Type of study and subjects	End points	Eggs consumed	CVD finding
Physicians Health Study ¹³⁷ <i>n</i> =21,275	P US male physicians	Heart failure (HF)	Up to 6/week ≥7/week	Not associated with incident HF Associated with increased risk of HF
West Australian ¹³⁶ <i>n</i> =514	P Australian Aborigines	CHD	More than 2/week	Increased risk of CHD (2.6-fold)
NHEFS ⁵⁹ <i>n</i> =9734	P US males and females	Stroke CHD	1 or >1/day	No increased risk of stroke, ischaemic stroke or CHD
NIPPON DATA80 ¹³⁸ <i>n</i> =6,288	P Japanese males and females	Stroke	≥2/day 1/day or >1/day	No effect on risk of fatal CHD events, stroke and cancer Increased risk in women (<i>P</i> =0.02)
Japanese ¹³⁹ 660 cases, 1277 controls	C Japanese males and females	MI	Up to 4 or more /week	No association between egg consumption and risk of acute MI
Nurses Health Study ¹⁴⁰ <i>n</i> =80,082	P Female nurses	Stroke CHD	Up to 1/day >1/day	No association with risk of CHD or stroke Increased risk of CHD for people with diabetes

Study and number of subjects	Type of study and subjects	End points	Eggs consumed	CVD finding
Health Professionals Follow-up Study ¹⁴⁰ <i>n</i> =37,851	P Male health professionals	Stroke CHD	Up to 1/day >1/day	No association with risk of CHD or stroke Increased risk of CHD for people with diabetes
Adventists Health Study ¹⁴¹ <i>n</i> =34,192	P Seventh Day Adventists	CHD	≥2/week compared to <1/week	Same risk of developing CHD
Italian women ¹⁴² 287 cases, 649 controls	C Italian females	MI	>2 portions*/week	No association between egg intake and non-fatal MI
Oxford Vegetarian Study ¹⁴³ <i>n</i> =11,140	P Vegetarian and meat eating	IHD	≥6/week	Associated with mortality from IHD (<i>P</i> <0.01)
Finnish cohort ¹⁴⁴ <i>n</i> =5133	P Finnish males and females	Fatal CHD	<1/day	No difference in egg consumption between those who developed fatal CHD and those who did not (<i>P</i> = 0.68 men; <i>P</i> = 0.94 women)
Framingham study ¹⁴⁵ <i>n</i> =912	P US males and females	Total CHD MI	Males: mean 6/week. Females: mean 4/week	No association between egg intake and total CHD or MI

P, prospective; C, case control; *Portion not defined

Nuts

Consuming nuts improves the lipid profile.
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Nuts contain about 50% fat (46–76%), and more than half is made up of MUFA and PUFA. A review by Coates and Howe⁶⁶ found a number of CVH benefits from consuming nuts, including contributing to the promotion of weight reduction, improving the lipid profile, benefiting glucose homeostasis and insulin sensitivity. A review of four large prospective epidemiological studies found a consistent cardio-protective effect with increased nut consumption.⁶⁷ The cardio-protective effect remained for a wide range of nut (and peanut butter) intake and was also observed across different populations. The

results indicated that frequent nut consumption may also prevent recurrent CHD events. The average risk reduction of CHD death was 8.3% for each serving of nuts consumed weekly (≈30 g). Intervention studies have confirmed the LDL-C-lowering effect of diets rich in walnuts, almonds and peanuts.¹⁴⁶

Vegetable diacylglycerol oil (DAG-oil)

There is not enough evidence at this time to make an evidence statement.
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This liquid vegetable oil (DAG-oil) is considered a novel food because 'it has no history of significant human consumption in Australia or New Zealand'.¹⁴⁷ DAG-oil contains 80% diglycerides, mostly consisting of the unusual 1,3 -species. Recent findings have shown that the consumption of this oil positively affects lipid metabolism, including the lowering of TG, decreasing postprandial lipaemia and reducing body fat compared with triacylglycerol.¹⁴⁸

The nutritional assessment of DAG-oil by FSANZ has concluded that 'although DAG-oil has no additional demonstrated nutritional benefits compared with triacylglycerol-based oils of similar FA composition, there is also no evidence to indicate an adverse impact on population nutrition, thus DAG-oil can be considered appropriate for general consumption'.¹⁴⁷ Initial findings from Japanese populations consuming DAG-oil with plant sterols have seen favourable impacts on serum cholesterol levels.¹⁴⁹

5. Type 2 diabetes, metabolic syndrome and CVH

'Whether a high-fat diet or a high-carbohydrate diet changes insulin sensitivity or leads to type 2 diabetes is still controversial.'⁷

While Diabetes Australia's lipid guidelines¹⁵⁰ found that diets high in SFA did not consistently adversely affect lipid levels in people with T2DM, there is some evidence to support a relationship between SFA, insulin resistance and T2DM.^{151,152} In a recent study, a decrease in SFA and increase in MUFA demonstrated improvement in insulin sensitivity,¹⁵³ but many studies do not show this result and the debate continues.⁷ Little is known about the possible effects of tFA intake on T2DM. Some observational and experimental studies support the hypothesis that tFA may increase the risk of T2DM, but inconsistencies exist¹⁵⁴ and no randomised controlled trials have been conducted.

A growing body of evidence suggests health benefits from the intake of n-3 PUFA. A Cochrane analysis of 23 randomised controlled trials found n-3 PUFA supplementation (mean 3.5 g/day) in T2DM lowered TG and resulted in very low LDL-C.¹⁵⁵ A meta-analysis of 18 randomised controlled trials of people with T2DM on 3–18 g/day doses of fish oil reported a significant reduction in TG with no significant effect on glycaemic control.¹⁵⁶ However, other studies have found that the beneficial effects of fish oil on lowering TG have been limited by the adverse effect on glycaemic control in diabetic patients.¹⁵⁷ More research on the effects of n-3 PUFA supplementation on diabetic patients is needed.

Epidemiological studies have evaluated the effects of n-3 PUFA intake (fish or fish oil) on the risk of diabetes, and a negative association has been observed.¹⁵⁸ The intake of foods enriched with n-3 PUFA have shown the same results.¹⁵⁸ Epidemiological evidence¹⁵⁹ suggests that increasing the PUFA:SFA ratio is associated with a reduced risk of T2DM.

A recent review¹¹ observed that at high intakes (>20%), tFA have the same effect as SFA on postprandial insulinemia in obese subjects with T2DM. At lower intakes, insulin sensitivity was not adversely affected in healthy individuals. The authors concluded that 'the limited number of human studies do not provide consistent evidence that, at current intakes in European countries, the effects of fatty acids on insulin sensitivity are not different for an isocaloric substitution of TFA by SFA, oleic acid or linoleic acid'.

Less well understood is the mechanism for dietary FA effects on the risk of diabetes. A number of possibilities have been suggested:

- the inhibition of the activity of desaturase enzymes, some of which are associated with higher insulin sensitivity¹⁶⁰
- the reduction of insulin sensitivity through the effect on increasing concentrations of interleukin-6, tumour necrosis factor- α , and prostaglandins¹⁵⁴
- through the FA composition of the cell membrane, by altering insulin receptor binding or affinity and by influencing ion permeability and cell signalling.¹⁵⁸

Between 19% and 29% of adult Australians have the *metabolic syndrome*, also known as *insulin resistance syndrome*,¹⁶¹ and the prevalence of the syndrome is estimated to be 20–25% worldwide.^{161,162} It is characterised by a clustering of metabolic risk factors, the most important being related to lipoprotein metabolism, that is, high serum TG levels, low serum HDL-C and an excess of small, dense LDL-C particles. CVD and T2DM are the primary clinical outcomes.

A review by Riccardi *et al.*¹⁶³ summarised the results of intervention studies performed in humans and concluded that the quality of dietary fat is able to influence insulin sensitivity as well as other metabolic abnormalities linked to insulin resistance. Substituting SFA with *cis*-unsaturated FA would have a beneficial effect on LDL-C and TG, and influence insulin sensitivity and some related metabolic abnormalities.

The beneficial effects of dietary changes in order to reduce the prevalence of the metabolic syndrome have been the focus of many clinical and epidemiological studies.¹⁶² Increasingly, the evidence has supported a diet rich in fruit and vegetables, legumes and wholegrains and one that includes fish, nuts and low-fat dairy products. The diets do not restrict total fat, but emphasize vegetable oils low in SFA and tFA. A recent study of Greek adults found that the Mediterranean diet was associated with a 20% lower risk of having the metabolic syndrome.¹⁶⁴ In addition, a modified moderate-fat Mediterranean eating pattern (35% of energy as fat) has been proven effective for weight loss.¹⁶⁵⁻¹⁶⁷

6. Dietary modifications and eating patterns

Dietary changes longer than two years can reduce cardiovascular events and total mortality among high-risk patients

A Cochrane meta-analysis of 27 randomised controlled trials found no significant effect from a reduced or modified dietary fat diet on overall mortality, cardiovascular mortality or cardiovascular events.⁶⁸ There were significant reductions in cardiovascular events and in total mortality among high-risk patients in trials lasting more than two years.

The Mediterranean dietary pattern has received much attention over the last decade because it has been shown consistently to protect against CVD. There are many forms of this diet, but the most 'traditional' is identified as the Cretan (Greek) diet.¹⁶⁸ The total fat in the traditional Cretan diet is about 40% of total energy, considerably higher than in most Mediterranean countries. The diet is characterised by its use of olive oil (high in MUFA) as well as plenty of n-3 PUFA, fruit and vegetables, wholegrains, pulses, nuts and fresh foods, with a reduction in SFA and processed foods.¹⁶⁸

Most of the evidence supporting the Mediterranean diet is from observational studies, and a comparison of studies is limited by varying definitions of the diet. Despite this, several reviews have shown a relationship between the Mediterranean dietary pattern and improvements in lipoprotein indexes, insulin sensitivity, and fatal MI.¹⁶⁹

Current Australian dietary recommendations²⁴ suggest a moderate dietary fat intake (20–35%) mainly from PUFA and MUFA and a moderate amount of CHO (45–65%); and these figures are supported by evidence.^{24,170} Consuming CHO and dietary fats within these ranges has been shown to promote weight loss, lower TG levels, maintain HDL-C levels and promote the maintenance of reduced body weight, while moderate-fat, Mediterranean-style diets are effective for weight loss and the prevention of the metabolic syndrome and CVD.¹⁷⁰

7. Gaps in the evidence

Areas of research that have been identified

- The relative health effects of SFA from plant sources derived either from natural fats or hydrogenation.²⁰
- The relative effects of liquid oils interesterified with SFA or fats high in SFA on the risk factors for CHD.²⁰
- The optimal balance of unsaturated FA for replacing SFA and providing the greatest CVH benefits.¹¹⁹
- The CVH benefits of consuming a high MUFA diet versus a diet lower in MUFA (and higher in carbohydrate).²²
- The relationship between cholesterol and total stroke mortality across all ages and blood pressures.⁵²
- The effect of tFA on LDL particle size (small, dense particles are positively related to CVD risk).¹¹
- Human intervention studies carried out on the effects of naturally occurring tFA.^{11,19}
- The CVH benefits of CLA.¹³²

Most data on the effects of consumption of tFA on cardiovascular risk factors exceed the levels of intake estimated for a typical Australian daily intake. Therefore, the Heart Foundation recommends that more data are collected for the intake of tFA at lower levels.

There is little evidence confirming that the blood lipid dose–response effect occurs at low levels of tFA intake, and the association with CHD incidence at low intakes is unknown. Therefore, it is not possible at this time to estimate the extent of disease reduction that would occur in Australia if tFA intakes were reduced below the current low intakes.¹⁷¹

The Heart Foundation suggests that evidence is collected from long-term studies of randomised controlled trials that give advice on eating patterns, such as the DASH diet and the Mediterranean-style eating pattern, with measures of CVD events, such as mortality and stroke.

8. Supporting Heart Foundation evidence papers

A review of the relationship between dietary fat and cardiovascular disease (1999)

The Heart Foundation reviewed the evidence for dietary fats and CVD in 1999.² The evidence is presented in Table 3.

This paper made recommendations on SFA, tFA, n-6 PUFA, n-3 PUFA, MUFA, dietary cholesterol and total fat.

The main recommendations from the paper were that:

- SFA and tFA together contribute no more than 8% of total energy intake
- n-6 PUFA contribute 8–10% of total energy intake
- at least two oily fish meals per week are consumed
- both plant and marine n-3 PUFA are consumed
- ALA intake be at least 2 g per day
- a proportion of dietary SFA should be replaced by PUFA and MUFA as a strategy for reducing intake of SFA.

For more information, see the position statement at

<http://www.heartfoundation.org.au/SiteCollectionDocuments/Dietary%20Fats.pdf>.

Dietary fat and overweight/obesity (2003)

The Heart Foundation's review on dietary fats and overweight/obesity¹⁷² aimed to determine if dietary fat was a risk factor for the development and progression of overweight and obesity. The review found that dietary fat is not an independent risk factor in the development and progression of overweight and obesity, but may increase the risk by increasing the energy density of the diet and encouraging excess energy intake.

The review assessed the effectiveness of fat reduction strategies for achieving weight loss in overweight and obese individuals, and weight maintenance in normal weight, overweight and obese individuals. The review found that fat reduction alone is not effective for achieving weight loss in overweight and obese individuals and limiting total energy intake is required. For weight maintenance, dietary fat reduction alone may be effective.

For more information, see the position statement at

<http://www.heartfoundation.org.au/SiteCollectionDocuments/Dietary%20fat%20ovob%20position%20NutDiet.pdf>.

Position statement on the relationships between carbohydrate, dietary fibre, glycaemic index/glycaemic load and cardiovascular disease (2006)

This Heart Foundation review on CHO¹⁷³ found that eating patterns low in fat and high in CHO may not be beneficial for lowering cardiovascular risk.

For more information, see the position statement at <http://www.heartfoundation.org.au/SiteCollectionDocuments/PP-584%20Nutr%20CHO.pdf>.

Phytosterol/stanol enriched foods (2007)

This update of the literature on phytosterol/stanol-enriched foods⁴ aimed to increase awareness of Heart Foundation recommendations around foods enriched with phytosterols for lowering cholesterol.

The main recommendation for people with high absolute risk of CVD, particularly those with elevated blood cholesterol levels, is that they would benefit from the cholesterol-lowering effect of phytosterols naturally occurring in plant foods and from food products enriched with phytosterols.

For more information, see the position statement at <http://www.heartfoundation.org.au/SiteCollectionDocuments/HF%20Phytosterols%20Stanols%20CVD%20PositionSt.pdf>.

Fish, fish oils, n-3 polyunsaturated fatty acids and cardiovascular health (2008)

The Heart Foundation reviewed the evidence supporting the relationship between fish and fish oil consumption and CVH.³ An extensive review of the literature was conducted, and the evidence was categorised according to the NHMRC levels of evidence for clinical interventions.

The position statement advises all Australians to consume:

- about 500 mg per day of combined docosahexaenoic acid (DHA) and EPA, and
- at least 2 g per day of ALA.

The position statement advises those with documented CHD to consume:

- about 1,000 mg/day of combined DHA and EPA, and
- at least 2 g/day of ALA.

For pregnant and breastfeeding women, and children, the advice is to follow the recommendations for healthy Australians and the FSANZ advice on mercury in fish.

For more information, see the position statement at http://www.heartfoundation.org.au/SiteCollectionDocuments/HW_FS_FishOils_PS_FINAL_web.pdf.

9. Terminology and abbreviations

ALA	Alpha-linolenic acid
CHD	Coronary heart disease
CHO	Carbohydrates
<i>cis</i> -MUFA	In a <i>cis</i> isomer, the two hydrogen atoms are locked on the same side of the double bond; <i>cis</i> -monounsaturated fatty acid
<i>cis</i> -PUFA	In a <i>cis</i> isomer, the two hydrogen atoms are locked on the same side of the double bond; <i>cis</i> -polyunsaturated fatty acid
CLA	Conjugated linoleic acid
CSIRO	Australian Commonwealth Scientific and Industrial Research Organisation
CVD	Cardiovascular disease
CVH	Cardiovascular health
DAG	Diacylglycerol oil
DHA	Docosahexaenoic acid, omega-3 fatty acid with 22-carbon chain C22:6n-3
DPA	Docosapentaenoic acid, omega-3 fatty acid with 22-carbon chain C22:5n-3
EPA	Eicosapentaenoic acid, omega-3 fatty acid with 20-carbon chain C20:5n-3
FA	Fatty acid
HDL-C	High-density lipoprotein cholesterol
HF	Heart failure
HR	Hazard ratio
IHD	Ischaemic heart disease
LDL-C	Low-density lipoprotein cholesterol
Lp(a)	Lipoprotein a
MI	Myocardial infarction
MUFA	Monounsaturated fatty acids
n-3 PUFA	Omega-3 polyunsaturated fatty acids
n-6 PUFA	Omega-6 polyunsaturated fatty acids
NHMRC	National Health and Medical Research Council
PHO	Partially hydrogenated oils
PUFA	Polyunsaturated fatty acids
SFA	saturated fatty acids or saturated fats
TC	Total cholesterol
TG	Serum triglycerides
tFA	trans fatty acids or trans fats
WHO	World Health Organization

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