EVIDENCE PAPER

DATE: August 2017

AUTHOR: Delvina Gorton, NZRD, PG Dip Diet, MHSc

Dairy and Heart Health

This paper summarises the evidence which underpins the Heart Foundation's position on dairy and heart health

CONTENTS

ABBREVIATIONS

ACE   Angiotensin converting enzyme

BCAA   Branched chain amino acid

BMIBody mass index

BP   Blood pressure

$C15:0$ Pentadecanoic acid

$C17:0$ Heptadecanoic or margaric acid

CHD   Coronary heart disease

CLA   Conjugated linoleic acid

CVD   Cardiovascular disease

DASH   Dietary Advice to Stop Hypertension diet

FFQ   Food frequency questionnaire

HDL   High density lipoprotein cholesterol

HR   Hazard ratio

IHD Ischaemic heart disease

LDL   Low density lipoprotein cholesterol

MI   Myocardial infarction

PCS   Prospective cohort study

RCT   Randomised controlled trial

RR   Relative risk or Risk ratio

T2DM   Type 2 diabetes

TC   Total cholesterol

TC:HDL Total cholesterol to HDL cholesterol ratio

TMAO   Trimethylamine-N-oxide

USDA   United States Department of Agriculture

BACKGROUND

Reduced-fat or low-fat dairy products (milk, yoghurt, cheese) have traditionally been recommended instead of full-fat versions to reduce saturated fat and energy intakes. The effect of the saturated fat in dairy on lipids has been the basis for recommendations to choose lower fat options. Eating unsaturated fats in place of saturated fat improves blood lipid levels, and reduces risk of heart disease.[1,2]

However, there are a range of different types of saturated fatty acids, and not all types have the same level of effect on blood lipids, or are equally linked to risk of heart disease. A single nutrient is unlikely to explain the full effect of a food on health outcomes, and it is possible that other components in dairy could counter or act in parallel with the effect of dairy fat on risk factors such as blood lipids.[3] [4] Therefore, it is relevant to consider the effect of the whole food on health outcomes, alongside the Heart Foundation paper on fats and fatty acids.

The purpose of this evidence paper is to look at the relationship between dairy and heart disease in order to assess if the recommendation to choose reduced-fat dairy products remains valid. It assesses evidence on the relationship of heart disease and risk factors with intakes of milk, yoghurt, cheese or dairy fat, dietary patterns that contain dairy, biomarkers of dairy-derived saturated fatty acids (pentadecanoic acid and heptadecanoic acid) and full versus reduced fat dairy.

This is an umbrella review, synthesising the evidence from recent systematic reviews, meta-analyses (summarised in appendix), and RCTs from Western countries. The literature search was conducted in mid-2015 and updated in November 2016.

NUTRIENT PROFILE OF MILK

Dairy products are made from cow's milk. Cow's milk contains approximately 87% water, 4.6% lactose (carbohydrate), 4.2% fat (mostly saturated fatty acids), 3.4% protein, 0.8% minerals (eg. calcium, magnesium, potassium) and 0.1% vitamins. There is some natural variation depending on the type of feed the cows eat (eg. grass or grain) and factors such as genetics or stage of lactation.[3,5]

The fatty acids in milk are derived from the cows feed and from microbial activity in the cow rumen.[5] Cows milk contains the most complex fat in the human diet with a large number of different types of fatty acids, however many are found in trace amounts.[5] The majority of fatty acids are saturated fatty acids, in particular the long-chain fatty acids palmitic acid (16:0), stearic acid (18:0) and myristic acid (14:0).[6] There are small amounts of a wide variety of trans fatty acids (3-7% of total fatty acids), with an abundance of trans-vaccenic acid, as well as some conjugated linoleic acid (CLA).[5] Microbial fermentation in the gut of humans and animals produces short chain fatty acids such as butyric acid (C4:0), and dairy is one of the few food sources of these.[3]

In New Zealand, cows are traditionally fed grass, whereas in the US they are fed grain. Grass-fed dairy contains slightly more fat-soluble nutrients such as vitamin A, carotenes, vitamin E, vitamin K2, omega-3 fatty acids, and conjugated linoleic acid. However, cow feed has increasingly been supplemented with palm kernel extract for extra energy. New Zealand is one of the largest importers of palm kernel extract in the world. Apart from the negative environmental impact of growing palm oil, palm kernel extract alters the composition of milk and increases milk fat and trans fat.[7] Grass type can also influence milk fat content. Clover-rich pastures, common in

New Zealand, increase the ruminant trans fat content due to the level of trans-vaccenic acid in plants.[7]

Milk also contains naturally occurring or intrinsic sugar in the form of lactose, at a little less than 5% by volume. Reducing fat levels does not alter the lactose content. Sugars that are added during processing, for example in the manufacture of low-fat sweetened yoghurts, are classified as 'free sugars'.

OTHER ORGANISATIONS' RECOMMENDATIONS ON DAIRY

Dairy products are recommended in dietary guidelines around the world to ensure adequate calcium intakes.[8] The New Zealand Eating and Activity Guidelines recommend "enjoy[ing] a variety of nutritious foods every day including: … some milk and milk products, mostly low and reduced fat". Low and reduced fat versions are recommended to reduce intake of energy and saturated fat. Similarly, Australian Dietary Guidelines recommend milk, yoghurt, cheese and/or their alternatives, mostly reduced fat, every day.[9]

The US Dietary Guidelines were updated in 2015. They recommend a healthy eating pattern that includes "fat-free or low-fat dairy, including milk, yogurt, cheese, and/or fortified soy beverages".[10] The recommendation for fat-free or low-fat dairy was based on health promoting dietary patterns, in particular the DASH diet. The Dietary Guidelines Advisory Committee reviewed evidence on dietary patterns and found "… that a healthy dietary pattern is higher in vegetables, fruits, whole grains, *low- or non-fat dairy*, seafood, legumes, and nuts; moderate in alcohol (among adults); lower in red and processed meats; and low in sugar-sweetened foods and drinks and refined grains."[11] It also noted that largely plant-based diets have been associated with less environmental impact in comparison to a higher consumption of animal-based foods, including dairy.[11]

Similarly, the Nordic review on dietary patterns and the American Heart Association Guidelines on lifestyle management recommend low-fat dairy can be included in eating patterns to lower risk of chronic disease.[12,13] The Australian Heart Foundation recommends 2-4 serves of reduced fat milk, cheese and yoghurt or alternatives each day.[14]

NEW ZEALAND CONTEXT

Milk, cheese and dairy products (classified in the National Nutrition Survey as cream, sour cream, yoghurt, dairy food, ice-cream, dairy-based dips) provide about 15% of adult New Zealanders' intake of Vitamin A, 28% of retinol, 31% of riboflavin, 30% of vitamin B12, 40% of calcium and 12% of zinc. In relation to macronutrients, they provide on average 19% of saturated fat intakes, 14% of protein and 6% of carbohydrate.[15]

In the last adult Nutrition Survey, reduced-fat or trim milk was reported as being used most of the time by 48% of the total population aged 15 years and over, while 43% usually used whole or standard milk. Males and females used reduced fat milk at similar levels, and its use increased with age in both groups. Trim or reduced-fat milk was more commonly used in the least deprived compared with more deprived households.[15]

EVIDENCE OVERVIEW

See Evidence Tables in the Appendix for a summary of findings from meta-analyses of prospective cohort studies and intervention studies

This evidence paper includes reviews of two main types of studies: randomised controlled trials (RCTs) and prospective cohort studies (PCS). Randomised controlled trials usually provide the strongest level of evidence.[16] However, conducting RCTs that are both large enough and long enough to determine the effect on outcomes like heart disease is largely prohibitive, due to the disease's long development period. This means that studies often use older participants more likely to experience cardiovascular events over the course of the study, and look at the effect of diet on shorter-term intermediate outcomes or risk factors. In general, RCTs on dairy and heart health were small and under-powered.[8]

Prospective cohort studies have the advantage of being able to examine large population groups over a longer period of time and to assess impact on long-term outcomes. However, they cannot determine if associations are due to cause and effect and suffer from limitations in dietary assessment methodology, such as under and over-reporting. Lack of randomisation means that they are susceptible to confounding from known or unknown factors.[17]

Milk and yoghurt consumption, particularly low fat varieties, are often accompanied by a healthier diet.[8] Higher dairy intake has been associated with a healthier lifestyle, higher socio-economic status and educational attainment.[18-20] While statistical adjustment is usually made for confounding factors such as these, residual confounding is always possible, and it could be that milk or dairy are a marker for healthier diets.[21] Furthermore, it is generally more difficult to deal with confounding when examining effects of individual foods.

Food frequency questionnaires, the most commonly used method of dietary assessment in prospective cohort studies, have been found to capture considerably less than half the inter-individual variability in whole milk consumption.[22] Dietary assessment tools with limited sensitivity are therefore trying to detect the effect of a single nutrient or macronutrient, within a single food, on complex clinical outcomes within a widely variable and changing diet. This makes it very challenging to detect the true effect.[23]

Most reviews did not grade the quality of evidence they were based on, and studies varied widely in design, quality, and dietary assessment methodology, with highly heterogeneous results. The definition of dairy, and high and low fat dairy, varied between studies and was often poorly defined, creating a lack of consistency in how foods were categorised. For example, full fat milk was often classified as high fat, even though its fat content is just over 4% in comparison to cheese's fat content of 30-40%. Some of the differences between studies could be from how dairy foods were defined, which ones are included in analyses, their differing macronutrient compositions, and what they are eaten with.

Guideline reviews

The 2010 US Dietary Guidelines review found:

- Moderate evidence that higher intakes of milk were associated with lower risk of cardiovascular disease, blood pressure, and type 2 diabetes in adults;
- Limited evidence higher intakes of milk were associated with lower risk of metabolic syndrome;
- Insufficient evidence to assess the relationship with serum cholesterol; and
- Strong evidence that there was no unique relationship to weight control.[8]

The review conducted for the Australian Dietary Guidelines found consumption of two servings per day of milk, yoghurt, or cheese was associated with reduced risk of ischaemic heart disease, myocardial infarction and stroke (fat level not specified). This was largely based on one meta-analysis.[24] Three servings of low fat dairy a day was associated with reduced risk of hypertension.[9]

A recent expert review of the state of nutrition evidence in relation to cardiovascular disease found moderately strong evidence that suggested a greater intake of low-fat and fermented dairy was inversely associated with CVD and blood pressure, and that it improved lipids.[25]

Cardiovascular disease

Dairy foods

Most reviews of prospective cohort studies do not show an association between total dairy products,[26-29] cheese[30] or milk[28,31,32,33] and risk of CHD,[26 27,31,32,33] CVD[26,28,30,32] or stroke[26,32,33]. Some reviews showed possible[34] or limited to moderate[8] evidence for reduced risk with dairy or milk intake, in relation to IHD,[35] stroke,[27] or CVD.[27,29,34] Associations can vary depending on the type of dairy product and other factors such as race or sex, and fat contents were usually not specified.[23,36,35]

Since these reviews, data from the PREDIMED trial has been published, analysed as a prospective cohort study using a repeated validated FFQ. It found dairy saturated fat was not significantly associated with CVD mortality in 7038 older Spanish adults at risk of CVD. The trend was towards reduced risk of CVD mortality but increased all-cause mortality with higher dairy saturated fat intakes. Plant-based saturated fats were associated with a 47% reduced risk for CVD.[37] Mediterranean-type diets usually favour fermented dairy foods such as yoghurt and cheese.[38]

Analysis of 14,815 cases in the Health Professionals Follow-Up Study and Nurses' Health Study I and II has found substituting 5% energy from dairy fat for carbohydrate (primarily refined carbohydrate and added sugars) was not associated with CVD. However, replacing dairy fat with whole grains, vegetable fat or polyunsaturated fat was associated with significant reductions in CVD, CHD and stroke risk.[39]

Substitution modelling such as this helps to clarify if findings are due to the food or nutrient being investigated, or the foods or nutrient it replaces (when standardising by percentage energy).[16,40] These are important considerations, as reducing saturated fat intake but eating more refined carbohydrate or sugar instead will not improve cardiovascular risk, for example, drinking soft drink instead of milk. A low saturated fat or low dairy fat intake can occur in the context of widely different diets, which will impact on cardiovascular risk regardless of the fat content. Because we eat a whole diet, not just one food, these analyses are important.

There are other important considerations when interpreting these findings:

- Results from analysis of *total* dairy intake do not differentiate between types of dairy products consumed. This can obscure beneficial or detrimental effects coming from various types of dairy products.[41,42] The type of dairy consumed also varies considerably from one population to the next, so studies may not be comparing the same exposure, making the findings difficult to interpret. One of the starting points of this evidence paper was the need to look at the effect of the whole food, and it is not possible to do that when different foods are all analysed together in a broad category.
- As an example, fermented products and probiotic yoghurt could have different effects to other dairy.[41,42,43] They can modify the gut microbiota,[44] and there is growing evidence on the importance of gut microbiota to health. Some probiotic strains could potentially modify lipid levels, although evidence is mixed and at an early stage.[45] Recent metabolomic research supports the role of dairy in gut microbial metabolism and gut health.[46]
- Similarly, total dairy fat intake may obscure differences. A study comparing cheese and butter with identical fat contents found different effects on LDL cholesterol,[47] and this has been supported in other studies.[48,49] Cheese could differentially effect lipids by promoting a prebiotic effect or faecal fat excretion due to its high calcium content.[50] Dairy fat is obviously one part of a whole food, and any associations with it may not be attributable to the fat, but to other components found in dairy.[3] Analyses do not differentiate between low intakes of high dairy fat and high intakes of low fat choices.
- The dietary context is also relevant, for example, traditional fermented cheeses eaten in Europe may not confer the same risk as processed cheese eaten on pizza in the US.[3] Furthermore, it is important to consider carbohydrate quality, which few studies did.[51]
- A number of prospective cohort studies started before or during the 1970s when full fat dairy consumption was the norm, but did not assess changes to lower fat options that occurred over time.[41] Thus, there may be a mismatch between what people actually consumed and what they said they consumed at the start of the study.

Full versus reduced fat

Qin et al compared highest versus lowest consumption of dairy for high and low fat products in a meta-analysis. For stroke, there was a small protective association with low-fat dairy intake but not full fat, and for CHD there was no association for either.[27] Qin noted that each of the studies included in the review had defined milk and dairy products differently.

The dose-response meta-analysis by Soedamah-Muthu et al also found no association between low- or high-fat dairy and CHD, based on a limited number of prospective cohort studies.[32]

Kratz conducted a narrative review of six prospective cohort studies assessing the relationship of full fat compared to low fat dairy with CVD or CHD.[3] Four studies found no associations with either. However, one study went further and assessed the ratio of full fat to low fat dairy and found it was positively associated with CHD. In the fifth study, full fat dairy was inversely associated with CVD mortality in an Australian cohort but not associated with all-cause mortality. Two studies looked at stroke and one found no association with either full or low fat milk. The other found full fat milk but not low fat milk was associated with increased risk of stroke.

Biomarkers

Accurate assessment of dietary intake can be challenging. There is usually a level of measurement error, reporting error and social desirability bias that impacts on results. Biomarkers have been explored to overcome these issues and provide an objective measure of dairy intake.

Dairy contains pentadecanoic acid (15:0), heptadecanoic (or margaric) acid (17:0) and trans-palmitoleic acid (trans 16:1n-7) that have been identified as markers of dairy fat intake.[52] Plasma and adipose tissue levels of C15:0 and C17:0 are now accepted biomarkers for dairy fat intake, but there is still some debate around their use. In a three-arm randomised controlled trial in New Zealand, Benatar found 15:0 was the only plasma fatty acid to change with increased intake of dairy (5.5 serves/day increase for one month), after statistical adjustment for multiple comparisons. No fatty acids changed with decreased dairy intake.[6] Whilst the association between dairy fat and 15:0 appears stronger than for 17:0,[53] it has not correlated with dairy intake in all cohort studies.[54,55]

Serum fatty acids can be altered by metabolic state[3] and factors such as age and smoking[56]. They can also reflect consumption of other meat fats[3,57] and higher intakes of fish[58], and can be made in the body from other fatty acids.[53,57] Similar levels of 15:0 and 17:0 have been found in a study of high-beef and no-dairy compared with a no-beef high-dairy group.[59] A study comparing concentrations of 17:0 in red blood cells found a similar level between vegans and dairy consumers, highlighting that it cannot be assumed to fully reflect dairy intake.[60] Furthermore, the ratio of dietary intakes of 15:0 to 17:0 are the reverse of what is found in plasma.[61]

There has been a limited amount of evidence that these odd-chain saturated fatty acids found in milk and dairy products (C15:0 and C17:0) could be associated with reduced risk of CHD and atherosclerosis.[62] A recent meta-analysis of four prospective cohort studies by Chowdhury et al identified an inverse association between C17:0 (heptadecanoic) fatty acid, which is moderately correlated with milk and dairy fat, and coronary outcomes. Results were not statistically significant for C15:0 or the combination of C15:0 and C17:0.[63] Some of the methodology and conclusions drawn in this meta-analysis received criticism, however they were not specific to the biomarker analysis.

Three prospective case-control studies that assessed C15:0 and C17:0 biomarkers were included in the Kratz review. In two studies, fully adjusted models found no statistically significant association between biomarkers of dairy intake and myocardial infarction, and another (the Nurses Health Study) found as plasma (but not erythrocyte) C15:0 increased so did risk of IHD. There was no association with C17:0.[3]

Since these reviews, the EPIC prospective cohort study found the sum of C15:0 and C17:0 was associated with a 9% lower risk of IHD. Confounding from statin use in those with higher SFA intakes was noted as a possibility.[36]

The effect of dairy fat on its own is hard to differentiate from the food in which it is found, and the effect seen in biomarker analyses could be due to other components in particular dairy products.[3] Biomarker analyses and observational data are not able to isolate the effect of dairy fat from that of the whole food.

Dietary patterns

The traditional Mediterranean diet has been well studied in relation to its positive impact on heart disease. Along with abundant use of plant foods and olive oil, it included moderate use of fish, dairy products, and alcohol with meals.[64] Dairy in traditional Mediterranean patterns was usually normal fat yoghurt and cheese made from goat and sheep milk (fermented dairy), but was not a major feature of the dietary pattern.

The traditional Okinawan diet is also well documented in relation to its heart health properties, and is very nutrient dense but low in calories. The diet is heavy in vegetables and fruit but reduced in meat, refined grains, saturated fat, sugar, salt with a low consumption of dairy products.[65]

These two contrasting dietary patterns suggest a moderate amount of dairy can be included in a heart healthy way of eating, but is not a necessary component.

Summary

Total dairy does not appear to be associated with an adverse effect on CVD or CHD, and some studies suggest a beneficial effect. However, it is noted that total dairy is a very imprecise tool that does not differentiate between potential effects of different dairy products and does not quantify what foods are actually being assessed, as these are likely to be highly variable between groups.

High-fat versus reduced-fat dairy products are not consistently defined and differing definitions limit interpretation. Results are inconsistent on effects, but overall meta-analyses do not show a direct association with CHD for either. There is, however, potentially a beneficial association between low-fat (and not full-fat) dairy and stroke. A more nuanced analysis looked at the ratio of high fat to low fat dairy and found a higher ratio was associated with increased risk of CVD.

The data does not suggest any reason for avoiding dairy foods in relation to heart disease. However, it is important to consider data from substitution modelling which is perhaps the most informative data. Although very few of these analyses have been conducted, they suggest that eating less dairy fat and instead eating unsaturated sources of fat or healthier foods is associated with reduced risk. Thus, dairy fat is not associated with increased risk, but replacing it with other foods or reducing dairy fat may be associated with reduced risk.

Blood lipids

The main rationale for recommending reduced over full fat dairy has been that eating unsaturated fats in place of saturated fat improves blood lipid levels, and reduces risk of heart disease.[1] Reducing dairy fat is a way to reduce saturated fat intakes. However, it may be more complicated than that. A recent study investigated the role of milk fat globule membrane on the impact of dairy on lipids. Butter has low levels of milk fat globule membrane, which encloses the fat, compared to other dairy foods. Over an eight-week period, milk fat enclosed in milk fat globule membrane did not alter the lipid profile, whereas milk fat without the membrane adversely impacted lipids.[66]

The impact of trans fat on heart health is also relevant to dairy products. In a cross-sectional study of 422 New Zealanders with significant coronary artery disease, two thirds of plasma trans fatty acids originated from ruminant (meat and dairy) sources. This was associated with increased risk of vascular disease.[7]

Of all the fatty acids, trans fatty acids have the most adverse effect on lipids, increasing LDL cholesterol and decreasing HDL cholesterol.[67-69] They also adversely affect endothelial function and inflammation. There are two sources of trans fatty acids in food: naturally occurring trans fats from ruminant animals (predominantly from meat and dairy fats), or trans fats produced during manufacture of foods (partially hydrogenated fats).[70] Dairy fat has about 3% trans fat from trans-vaccenic acid (trans-11 18:1), trans-palmitoleic acid (trans-9 16:1) and conjugated linoleic acid.[71] The level in butter is a little higher, with 3-5% of fat as naturally occurring trans fats.

It has been proposed that naturally occurring and manufactured trans fats have different effects. However, this could be due to the amount of ruminant trans fatty acids consumed being too low to adversely effect heart disease risk.[70] Whilst some meta-analyses suggest effects could be similar if consumed in similar amounts, others do not.[70,72] The latest review on trans fats for the World Health Organization found effects of ruminant and industrial trans fats on lipids were mostly in the same direction, although there was less data available on ruminant fats.[73] There may also be differences by type of naturally-occurring trans fat, with one study finding trans-vaccenic acid but not CLA having a similar effect to industrial trans fat.[74]

This section should be considered in the context of the Heart Foundation evidence review of fats and fatty acids. Dairy fat was a major source of fat in many of the trials on saturated fat.[75]

Dairy foods

The USDA 2010 Dietary Guidelines review found insufficient research on the relationship between milk and milk products and blood cholesterol to make a recommendation.[76] The advice in their 2015 guidelines to choose low-fat dairy was based on dietary patterns research, where low-fat dairy has been included in dietary patterns that reduce risk of heart disease.[10]

In a review of meta-analyses and RCTs, Da Silva et al found no clear role of dairy products on the plasma lipid profile.[77] Of 18 studies, five found a beneficial effect of dairy on lipids, one found a negative effect, and 12 found no effect. However, most of these trials were not designed with lipids as a primary outcome, and were weight loss trials, which in itself affect lipid levels.

Some studies have compared the effect of dairy to other foods and shown that in comparison to carbohydrate or unsaturated fats,[26] canola oil,[78] tofu or modified fat cheese[79] dairy adversely effects lipid levels. Another study found adding 96-120g cheese per day increased HDL cholesterol by 5%, although this would be expected. The impact on the full lipid profile was not assessed and there were multiple changes to the control and intervention diets that would be expected to distort the results.[80] Overall, these RCTs show potential for dairy fat to adversely impact lipids in comparison to unsaturated fats and some foods.

Studies on the effect of dairy on triglycerides are limited and generally small and poor quality, and triglycerides were not the main research focus. As the evidence stands, it does not suggest an effect of dairy on triglycerides.[49]

The effect of dairy on sub-particles of LDL was mentioned in three reviews. German[41] and Gibson[23] both cite a single study that suggested dairy fats raised large buoyant LDL cholesterol instead of small dense LDL (which some consider more atherogenic). This was a cross-sectional study in healthy Swedish men, which investigated the effect of different fatty acids on particle size. The fatty acids commonly found in dairy were associated with fewer small dense LDL.[81]

Drouin-Chartier[49] found reduced fat milk had no impact on LDL particle size in two studies (although in one study the control diet could be expected to increase particle size[48]) and in a further study it increased LDL particle size. In a comparison of DASH-type diets using either full-fat or low-fat dairy, full-fat had no effect on LDL particle size, whereas low-fat had an adverse effect and reduced particle size.[82] The low-fat dairy group had a much higher sugar intake, however, which could be expected to adversely impact on particle size.

Small dense LDL may be more atherogenic than large, buoyant LDL; however, both are still likely atherogenic.[83] Limited data exist on these effects and particle size is not currently a diagnostic test as its ability to predict risk is unclear. The impact on sub-fractions is usually not measured in studies, making it difficult to ascertain the true effect. The impact of dairy fat on LDL particle size is not well researched, but available evidence on the impact of saturated fat suggests replacing it with unsaturated fats would reduce all sizes of LDL.[75]

Full versus reduced fat

Benatar assessed nine RCTs with 702 participants and did not identify a statistically significant effect of full-fat versus low-fat dairy on LDL or HDL cholesterol.[84] Full fat dairy non-significantly increased LDL by +3.30mg/dL (from five studies) and low fat non-significantly reduced it by -1.42mg/dL (from three studies). Confidence intervals were wide, with insufficient data to give a precise estimate. These are small changes, but they could be meaningful at a population level. One of the early studies not captured in this review, but included in a narrative review by Drouin-Chartier, was a six-week RCT comparing skimmed and full-fat milk. LDL-cholesterol was significantly lower in the skimmed milk group post-intervention, with an -0.32mmol/L difference.[49]

There have been three subsequent trials, with two RCTs finding no differential effect on lipids between full fat and reduced fat cheese.[85,86] However, when reduced-fat milk, yoghurt and cheese were compared to an energy-equivalent control it resulted in a small but statistically significant increase in LDL cholesterol (+0.08mmol/L) over four weeks.[87]

In narrative reviews, Da Silva identified two RCTs that compared the effect of full fat and reduced fat milk or dairy on lipids. One found non-fat milk improved the lipid profile but full fat did not, and the others found full fat increased both LDL and HDL cholesterol.[77] The overall effect on the TC:HDL ratio was not reported. Huth discussed two small crossover studies that showed whole milk increased LDL and TC in comparison to reduced-fat milk.[26]

Summary

The evidence is mixed between no general effect of dairy on lipids, improvements in lipids when other foods are substituted for dairy, and an adverse effect of full fat dairy on LDL cholesterol (and a non-significant trend towards an adverse effect in meta-analysis). There was little assessment of overall impact on TC:HDL ratio. For people aiming to reduce their LDL cholesterol levels, reducing dairy fat may help make a small improvement.

Body weight or body composition

There has been interest in the effects of dairy on body weight as it is theorised that dairy protein could increase satiety[88] and help regulate appetite,[89,90] reduce the blood glucose response,[89,91] calcium in dairy could bind with fats in the intestine

and reduce their absorption,[92,93] and conversely low calcium levels could allow an endocrine response that favours fat storage.[94]

There has also been interest in the effect of conjugated linoleic acid (CLA) on body weight. CLA is a class of naturally occurring trans fatty acids with bioactive properties.[95] The main food source for humans is ruminant meat and dairy fat.[96] CLAs are fat-soluble so are not present in non-fat milk. CLA has been investigated in relation to a variety of factors including body fat, CVD, lipids, and inflammatory responses.[97] Effects in relation to lowering risk of CVD have been seen in animals or in vitro models, but have not translated to humans.[98,99] FSANZ have noted a potential adverse effect of CLA on CVD through an adverse effect on blood lipids and glycaemic control and assessed that evidence does not adequately support its safety.[100]

There have been a small number of human studies mostly using synthetic CLA supplements. These potentially show a very small effect of CLA on body weight and composition.[98,95] However, this evidence is weak[101] and the low amount found in dairy products is unlikely to have this effect.[3,92] Studies that have investigated the effect of dairy products fortified with additional CLA have failed to find an effect on body weight.[95]

Dairy foods

Findings from prospective cohort studies on the impact of dairy on body weight are inconsistent. In a review of 19 prospective cohort studies, eight found total dairy was associated with a protective effect against weight gain, and one found a protective effect only in overweight men. Of the remainder, seven found no effect, one reported an increased risk in children, and two reported mixed results depending on the type of dairy food.[102] Once again, a major limitation of assessing total dairy is that type of dairy consumed varies considerably between groups, therefore these studies are not assessing the same exposure. Intake of other macro- and micronutrients will vary along with differences in dairy intake.

A review of the specific effect of yoghurt, which included two small short-term RCTs and five prospective cohort studies, also had mixed results which overall did not suggest any particular benefit of yoghurt on body weight.[103]

The most recent meta-analysis of 24 studies on body weight by Schwingshackl attempted to determine the quantitative effect of dairy on body weight in adults from cohort studies.[104] Overall, there was no association between dairy and increased body weight, but there was an association with reduced waist circumference. Similarly, higher intakes were associated with reduced risk of overweight. There may be differences by food type, with yoghurt associated with reduction in body weight and cheese with increases:

- Body weight: the pooled analysis showed a non-significant 14.4g/year body weight increase with each additional serving of full fat dairy; and a non-significant -6.02g/year decreased body weight with each serving of low-fat dairy. When looking at individual dairy foods, yoghurt was the only food associated with a statistically significant decrease in body weight, whereas cheese was associated with an increase in body weight for each additional serving.

- Waist circumference: milk, yoghurt and cheese were associated with a 2mm decrease in waist circumference over a year for each serving

increase. There were no statistically significant associations when comparing high versus low intakes of dairy or dairy type.

- Risk of overweight, abdominal obesity or weight gain: reduced risk of overweight and abdominal obesity with higher compared to lower dairy consumption (one study was specific to yoghurt). There was no association with weight gain, but sensitivity analyses showed a significant reduction with whole fat dairy.

A Mendelian randomisation study in Danish adults found no association between milk intake and risk of overweight or obesity (OR 1.01 (1.00, 1.02) per 1 glass milk/week).[105] These types of studies apply randomisation retrospectively to cohort data based on a genetic variance and thereby limit the effects of confounding. In this case it was lactase deficiency as people with this genetic type consume less milk products than those without it.

Children

Dror reviewed observational and intervention studies on dairy and adiposity in pre-schoolers, children, and adolescents in developed countries. The majority of the 36 studies were cross-sectional. Overall, the meta-analysis showed no association between dairy intake and adiposity, and no difference by dairy type, study design or sex. When assessed by age group, this finding remained true for pre-schoolers and children, but there was a modestly protective effect of dairy for adolescents. The authors noted that accurate self-report of dietary intake can become more problematic in adolescence. Of note was one small cross-sectional study that found a protective effect of dairy on overweight in the total sample, but not in the sub-group of plausible reporters. In another study, under-reporting of higher energy density foods, including dairy, was found in 45% of overweight girls. Few studies separately considered dairy type, and most did not consider sweetened drinks as a confounder.[106]

A recent meta-analysis of prospective cohort studies found dairy intake was associated with an overall protective effect against overweight or obesity in children and adolescents. Based on four studies, each increased serving of dairy per day was associated with a 13% lower risk of overweight or obesity in children. The association with body fat was not statistically significant in two studies, but trended towards reduced body fat with increased dairy intake (there was high heterogeneity and possible publication bias). However, BMI increased by 0.02kg/m^3 with each additional dairy serve per day based on five studies. Data from nine studies that were unable to be combined in the meta analysis were inconsistent with these overall results.[107]

Since these reviews, results from the HELENA prospective cohort study in adolescents found milk and yoghurt were associated with lower body fat, but not cheese or dairy desserts.[108]

Randomised controlled trials

Randomised controlled trials do not suggest benefit of dairy on body weight in adults[109] or in children[106]. Chen et al conducted a pooled analysis of 29 RCTs (n=2101) in adults and found increased dairy intake did not reduce body weight or body fat in the long term or in studies where energy was not restricted.[102] Studies that showed a beneficial effect were short term and energy restricted.[110,111] Similarly, three other reviews of RCTs found weight loss or body fat reduction occurred when it was due to the combination of an energy-restricted diet plus dairy

products, not the inclusion of dairy products alone.[77,112] However, dairy could have a beneficial effect by helping maintain lean mass during energy restriction.[90,113 112,114]

Another way of looking at the evidence is to assess the effect of increasing dairy intake. A meta-analysis of RCTs found increasing dairy intake by a mean of 3.4 serves/day in ad libitum diets lead to increased weight in both low and whole fat dairy (+0.41kg greater weight gain in low fat group) but had little effect on other cardio-metabolic risk factors.[84]

Full versus reduced fat

Kratz et al identified 16 observational studies (10 prospective, five cross-sectional, one retrospective) assessing dairy fat consumption, 11 of which found greater consumption of dairy fat or high-fat dairy at baseline was associated with being leaner or gaining less weight over time compared to people who consumed less.[3] The largest study in the review (the Health Professionals Follow Up Study) had similar findings, but at the same time found increasing high fat dairy over time led to increased weight gain.

There is potential for reverse causality in these findings as high-fat dairy may be eaten because body weight was not an issue or to gain weight and conversely low-fat may be eaten to reduce weight. To assess for this, the authors looked at six studies that adjusted for baseline body weight. Four of these studies still showed inverse relationships between dairy fat and obesity (as dairy fat goes up, risk of obesity decreases), suggesting reserve causation does not fully explain the association. The authors also examined differing effects by country, and found an inverse association was common in European countries, and less common in the United States.[3] There are differences in how dairy is consumed, with the United States having dairy in foods such as ice-cream and pizza, rather than traditional cheeses and yoghurts in European countries.

In subsequent studies:

- Prospective follow up of middle-aged and elderly women from the Women's Health Study found those who were normal weight at baseline and were in the highest quintile of full-fat dairy intake had 200g less weight gain compared to the lowest quintile of intake over 17 years of follow up. The low-fat dairy group had a non-significant 90g less weight gain. The highest quintiles of dairy intake were 1.3 servings/day for full fat, and 2 servings/day for low-fat.[115] However, the highest consumers of full fat dairy were also the highest consumers of low-fat dairy.

- Smith et al analysed how protein foods are exchanged and the relationship with long-term body weight. Change in low fat dairy intake was positively correlated with carbohydrate intake. This suggests that lowering the fat content of dairy was countered with consumption of more carbohydrate, so no impact on body weight would be expected.[116]

Biomarkers

There have been five biomarker studies, all of which found an inverse relationship between dairy fat and body weight. All were cross-sectional studies and two did not make any adjustment for potential confounders.[3]

Summary

Overall, evidence does not support a special effect of dairy for weight control without energy restriction in adults, but it could help maintain lean mass during weight loss. There is a discrepancy between cohort studies and randomised controlled trials. Cohort studies suggest there could be a benefit in adolescents and adults, but this is not supported by RCTs, which found no effect in adults or children. Cohort studies also suggest high fat dairy could be associated with less weight gain, although this is more common in European countries where different types of dairy tend to be eaten.

Blood pressure

There are a variety of ways proposed that dairy could influence blood pressure. One mechanism is through its micronutrient content, specifically potassium, calcium, phosphorus, and vitamin D (milk is fortified in the US).[117,118] RCTs on the effect of calcium and/or potassium and magnesium have found modest reductions in blood pressure of -1.27 to -4.6 mmHg for SBP, and -0.24 to -3.8 mmHg for DBP.[119] However, the effect of calcium on blood pressure could be threshold dependent, and may only improve in low calcium consumers.[120] Calcium, magnesium, potassium and vitamin D, can also act on the arterial wall.[118]

Milk is also rich in essential and branched chain amino acids. Some of their metabolites have bioactive properties that can reduce blood pressure.[117,121-123] There is some evidence from RCTs of a beneficial effect of protein on blood pressure, although the evidence relates primarily to plant protein (with insufficient data on dairy), and these findings are inconsistent in epidemiological data.[124] Furthermore, milk peptides in casein and whey could block the action of angiotensin converting enzyme (ACE) resulting in blood vessels remaining dilated.[118,119] Probiotics do not currently seem to have an influence, although their effect could be strain specific.[125] Reduced fat dairy, particularly yoghurt, has also been associated with reduced arterial stiffness in people with type 1 and 2 diabetes.[126]

Dairy foods

The 2010 USDA Dietary Guidelines systematic review found a moderate body of evidence suggesting an inverse relationship between dairy and blood pressure. However, they did not feel there was evidence to support an independent effect of total dairy on blood pressure, which suggests the association could be due to other confounding factors. There was a lack of adequately powered RCTs, and the evidence relied mostly on prospective cohort studies.[8] Two subsequent narrative reviews built on the USDA review and also found evidence for improved blood pressure,[117] especially in people with hypertension or pre-hypertension.[120] However, Benatar's meta-analysis of RCTs did not find any statistically significant effect of increased dairy on blood pressure, or any difference by fat content.[84]

Since these reviews, the Framingham Heart Study found three dairy servings compared to one dairy serving per week was associated with a smaller increase in systolic and diastolic blood pressure over an average 15 year follow up. Similarly, low-fat dairy was associated with a smaller increase in systolic blood pressure, although the impact seemed to decrease over the long term.[127]

The discrepancy between RCTs and cohort studies could potentially be due to dairy exerting an influence over a longer period of time and minimising age or weight-related blood pressure changes.[49] It could also be due to the effect seen in cohort studies being due to other confounding factors, in line with the USDA findings.

Full versus reduced fat

There were six prospective cohort studies in the 2010 USDA systematic review on the effect of dairy on blood pressure. Of the six studies, one found reduced risk of hypertension with low-fat dairy, reduced risk with low-fat but not high-fat dairy in three studies, and two with no association of dairy with hypertension.

An update to this review identified one further methodologically strong cross-over RCT.[117] In 45 normotensive men and women in Spain, 3.5 serves of full-fat milk and yoghurt per day increased systolic blood pressure and body weight over an eight-week period, whereas low-fat milk and yoghurt did not. However, the difference in overall effect on blood pressure (systolic and diastolic combined) was not statistically significant.[18]

Ralston compared the effect of full fat vs reduced fat dairy, and cheese vs milk or yoghurt on blood pressure from five cohort studies. There was only a statistically significant reduction in blood pressure with low fat dairy. There was no association with cheese, but milk and yoghurt were associated with reduced risk of raised blood pressure.[128] A dose-response meta-analysis found a slightly reduced risk of hypertension with low-fat dairy (based on six cohort studies), milk and total dairy, but not for full-fat dairy, cheese, yoghurt or fermented milk products.[129]

Since these reviews, a randomised controlled crossover trial found the addition of four serves per day of low-fat dairy reduced high blood pressure by 3mmHg in 49 middle and older aged adults.[130]

Dietary patterns

The review by McGrane et al discusses two studies on dietary patterns: DASH and SUN.[117] The Dietary Approaches to Stop Hypertension (DASH) study trialled a dietary pattern approach to reducing blood pressure. There were three main approaches compared: a control group on a Western diet, a diet high in fruit and vegetables, and a combination diet high in fruit and vegetables plus low-fat dairy. The greatest benefits on blood pressure were seen in the combination group and were most pronounced in people with hypertension and African-Americans.[131,132] These findings were supported in the DASH-Sodium trial.[133] Both studies also identified improvements in LDL cholesterol.[133]

Further support for the DASH diet comes from the SUN study in Spain. This prospective cohort study looked at occurrence of hypertension over nearly five years and adherence to different dietary patterns. Only a DASH-type dietary pattern was inversely associated with hypertension. Mediterranean dietary patterns, dietary guidelines based patterns, and full-fat dairy were not associated with lower risk of hypertension.[134]

It is worth mentioning a recently published crossover RCT that looked at the role of full vs reduced fat dairy in the DASH diet. It was a small (n=36), short-term study that compared a control diet, the original DASH diet, and a full-fat dairy DASH diet (higher fat and lower carbohydrate). It found similar reductions in blood pressure with full fat and reduced dairy as part of a DASH diet.[82] Whilst this could provide useful information, the full fat dairy group also reduced free sugar intake by 65g, which could independently improve blood pressure.[135]

Ndanuko et al investigated a wider range of dietary patterns. They found evidence for the DASH, Nordic, and Mediterranean diets lowering blood pressure. With no other intervention, overall they achieved a 4.3 mm Hg reduction in systolic blood pressure and a 2.3 mm Hg reduction in diastolic blood pressure. Similarities

between the dietary patterns were being rich in vegetables and fruit, whole grains, legumes, seeds, nuts, fish and dairy.[136]

Summary

There is potentially a reduced risk of hypertension with dairy over the longer term, but this appears specific to low-fat dairy.

Type 2 diabetes

Proposed mechanisms for a protective effect of dairy intake on type-2 diabetes are alterations in mitochondrial function through the effect of leucine, changes in gut microbes, influences on inflammation and cardiovascular function, and possible metabolic activities of trans-palmitoleic acid.[137] Again, calcium and magnesium or dairy protein could also be involved. Specifically in relation to cheese, it has been proposed vitamin K2 found in fermented dairy products or Vitamin D could account for any potential benefits.[138]

Dairy foods

Meta-analyses of prospective cohort studies suggest a higher dairy intake is associated with a lower risk of type-2 diabetes. Based on five prospective cohort studies, Elwood found a 15% lower risk of type 2 diabetes associated with high versus low intake of dairy.[35] Gao *et al* found a 6% lower risk of type 2 diabetes associated with each 200g per day total dairy consumption. Aune found a similar risk reduction with 400g dairy per day.[139]

Chen updated data in three US cohorts included in previous reviews - the Health Professionals Follow-Up Study, and Nurses' Health Study I and II. There were 15,156 cases of type 2 diabetes, and neither total dairy, low-fat or high-fat dairy were associated with risk of diabetes. However, yoghurt was inversely associated in all three cohorts. Chen also updated a meta-analysis of prospective cohort studies with this data and had similar findings.[140]

Gijsbers *et al* combined data from all available prospective cohort studies (n=22 cohorts), including Chen's updates and other recently published papers, to try and resolve these conflicting findings. The studies involved 579,832 individuals and 43,118 cases of type 2 diabetes. Total dairy just reached statistical significance and was associated with a 3% reduced risk of type 2 diabetes with each 200g serve. The association was stronger than this in studies that did not adjust for major confounders. There was no association with high-fat dairy, and a marginal reduced risk with low-fat dairy.[141]

A study using Mendelian randomisation assessed the effect of milk intake on type 2 diabetes and overweight or obesity. Mendelian randomisation is a technique that uses genetic differences to apply randomisation (which essentially occurred in utero) to observational studies. This method reduces the potential effects of reverse causation and residual confounding. In this Danish study, 97,811 people were grouped according to whether they had the genotype for lactase persistence (that is, lactose tolerant versus intolerant). Comparisons were then made to assess risk of type 2 diabetes and overweight/obesity between groups. Drinking milk compared to not drinking milk was not associated with risk of type 2 diabetes or overweight/obesity. Results were similar when people with known CVD or diabetes were included. It did not differentiate between full fat and reduced fat dairy.[105] Whilst this approach is methodologically strong, it has only been applied to one cohort.

Full versus reduced fat

Kratz identified eight prospective cohort studies assessing the association between dairy fat and type 2 diabetes. Three out of eight studies found an inverse association with dairy fat intakes at baseline, one found inconsistent associations, and the remaining four found no association. Three of the studies found an inverse association between low-fat dairy and type 2 diabetes incidence (all were studies from the United States). Morio et al found a similarly mixed picture.[51]

Meta-analyses of prospective cohort studies have more consistent findings. Low-fat, but not full-fat dairy, has been associated with reduced risk of type 2 diabetes in four meta-analyses.[138] [139,141,142] Yoghurt [141,142] and 50g/day cheese[138,139] were also associated with reduced risk. The review by Gijsbers contains the most comprehensive and recent meta-analysis, and it found only a marginal association with low-fat dairy, and no association with high fat dairy.[141]

Biomarkers

In a meta-analysis for the World Health Organization, using the rigorous GRADE methodology, De Souza et al identified five studies which showed an overall inverse relationship between *trans* 16:1 n-7 and type 2 diabetes (risk ratio 0.58, 95% CI 0.46 to 0.74). Quality of the evidence and certainty in the estimates was graded as very low, with serious risk of bias.[70]

Dietary patterns

Prospective analysis of a sub-group of 3,454 older Mediterranean participants in the PREDIMED trial found total dairy was protective against type 2 diabetes, but this was mainly attributed to low-fat milk and yoghurt.[143] No association was found for full-fat dairy, cheese, processed cheese, and a grouping of cheese, cream and butter.

Summary

Low-fat dairy or yoghurt may be associated with a small reduction in risk of type 2 diabetes. Total milk intake was not associated with type 2 diabetes in a methodologically strong Mendelian randomisation study.

Metabolic syndrome

The potential effect of dairy on metabolic syndrome has been suggested to be from the effects of calcium on improving lipids, peptides inhibiting ACE and therefore improving blood pressure, BCAA's increasing post-prandial insulin secretion and therefore regulating plasma glucose, and leucine potentially modulating mTOR and thereby decreasing glucose.[92,144,145] Calcium and magnesium in dairy could also potentially improve insulin sensitivity.[146]

Dairy foods

A review of 10 cross-sectional studies and 3 prospective cohort studies by Crichton *et al* found dairy intake was inversely associated with metabolic syndrome in seven studies. Three found no association and the remaining three studies had mixed results. The authors noted methodological differences, potential biases and other limitations that limited their ability to draw conclusions. These included lack of definition of dairy foods and the amount consumed; lack of repeat measures in prospective cohort studies; use of a different number of criteria for diagnosis of

metabolic syndrome; and failure to control for confounders. However, study quality did not appear to be related to study results.[147]

The three prospective studies found:

- No protective effect of dairy against development of metabolic syndrome in an elderly Dutch population.
- Milk and dairy intake associated with reduced prevalence of metabolic syndrome in men.[148]
- Dairy was inversely associated with metabolic syndrome only in those who were overweight but not normal weight.[147]

Cross-sectional studies have suggested differing effects between men and women, different types of dairy (cheese was positively associated and yoghurt negatively associated with metabolic syndrome), and by obesity status.[92,148]

Meta-analyses have found that higher total dairy intake is associated with reduced risk of metabolic syndrome.[149-151] A recent meta-analysis of prospective cohort studies found a relative 15% reduced risk of metabolic syndrome with the highest versus lowest dairy intake. Each serve per day increase in dairy consumption was associated with a 12% reduced relative risk.[150]

Turner et al reviewed RCT evidence specifically on the effect of dairy intake on insulin sensitivity. In weight stable adults, four interventions found a beneficial effect of dairy on insulin sensitivity, one had a negative finding, and five showed no effect. Studies longer than three months were more likely to show beneficial results. Overall participant numbers were small. They chose weight stable participants because interventions that include dairy are often confounded by changes that lead to weight loss. Studies were selected where only dairy was altered, and there were no other lifestyle or dietary changes.[152]

Drouin-Chartier[49] gave an overview of interventions published since the Turner review. Reduced fat milk and yoghurt or cheese had no impact on glucose and insulin concentrations in three studies.[80,153,154] Fasting insulin and HOMA-IR were lower after four serves of low-fat dairy versus two serves/day over six months.[155] Low-fat dairy increased fasting insulin and HOMA-IR in overweight men over four weeks in comparison to meat.[156]

Benatar conducted a meta-analysis of RCTs and did not find any statistically significant effect of increased dairy on insulin resistance (four studies) or blood glucose (eight studies).[84]

Since these reviews:

- A randomised crossover trial in 47 overweight adults in Australia found fasting insulin increased but fasting glucose remained the same, indicating greater insulin resistance, after a high dairy diet for four weeks.[156]
- A cross-sectional study found higher dairy intake (2.4 serves/day) was associated with increased insulin resistance (HOMA-IR) in 272 middle-aged women. This study was cross-sectional, so it cannot show cause and effect. Its strengths were that it used a 7 day weighed food record to measure dietary intake and body fat was accurately measured using a Bod Pod.[157]

Full versus reduced fat

In the review by Kratz et al, six out of 11 observational studies found higher dairy fat consumption was associated with better metabolic health (one retrospective study,

four cross-sectional studies, two prospective case-control and four prospective cohort studies). One study partially supported it, three found no association, and one showed an adverse effect (but had an unusual study design). There were less favourable associations in US compared to European studies.[3] Of the prospective cohort studies in the review, one found no associations with dairy fat, one found some inverse associations with low-fat and full-fat, and the other found an inverse association with trans-palmitoleate as a biomarker of dairy fat.

Recently published studies included:

- Data from a cohort within the large five-year PREDIMED randomised controlled trial was analysed as a prospective cohort study. It found high versus low intakes of low-fat milk, and low-fat and full-fat yoghurt (but not total yoghurt) were associated with reduced risk of metabolic syndrome. Full-fat milk was not significantly associated with metabolic syndrome, although the trend was towards increased risk. Cheese was associated with increased risk in this older Mediterranean population at high cardiovascular risk. Intakes were assessed yearly and the FFQ had good reproducibility and validity for dairy products.[158]
- In cross-sectional analysis of a healthy Brazilian population, total and full-fat dairy intake was inversely associated with metabolic syndrome, whereas low-fat was not.[159]

Dietary patterns

A review of dietary patterns from prospective cohort studies and high quality RCTs up until 2012 found evidence for beneficial effects of the Mediterranean Diet, DASH diet, and the Nordic Diet on metabolic syndrome. These diets typically include a dairy component.[160] In the DASH diet it is specifically low-fat dairy.

Summary

There is a limited amount of data on metabolic syndrome and it has inconsistent results. However, meta-analyses of prospective cohort studies suggest there could be an association with lower risk of metabolic syndrome, although these analyses used total dairy (with associated limitations).

Taken as a whole, studies do not suggest a beneficial effect of dairy on insulin sensitivity. However, it may be that some intervention studies have been too short to determine the true effect.

Inflammation

The fatty acids, micronutrients, amino acids and other components of protein in dairy could all potentially play a role in inhibiting or promoting inflammation.[71]

Dairy foods

Cross-sectional studies have found higher intakes of dairy are associated with lower levels of systemic inflammation, but intervention studies have conflicting results.[161] A review of randomised controlled trials on dairy and biomarkers of inflammation found eight studies in overweight or obese people. Only one study had inflammation as its primary outcome, and it found dairy improved markers of inflammation. Three of the remaining seven studies also found improvements, and four found no effect.[162] Differences are likely due to the varying dairy products studied, whether inflammation was a primary outcome, and the biomarker used.[161]

Benatar conducted a meta-analysis on six randomised controlled trials with 400 participants, and found overall no significant change in C-reactive protein with higher dairy intake.[84]

Drouin-Chartier reported on five studies published since the Benatar review that showed no impact of low or high fat dairy or low-fat milk on inflammatory markers or gene expression. A further cross-over study, which was very small (n=12), found no difference in inflammatory markers except IL-6 which was higher on full-fat non-fermented dairy compared to low-fat dairy.[49]

Two further studies were identified:

- A recent six-week randomised cross-over study in 37 women with metabolic syndrome found increasing low-fat milk intake improved markers of inflammation.[163]

- A small cross-over study in Swiss men found neither a high-fat dairy meal nor addition of milk to a high-fat meal differentially affected acute postprandial inflammation in comparison to a high-fat non-dairy meal.[164] This study suggests the addition of milk does not lower the inflammatory response from a high-fat meal, and that a meal high in dairy fat has the same impact on the inflammatory response as a meal high in fat from non-dairy sources.
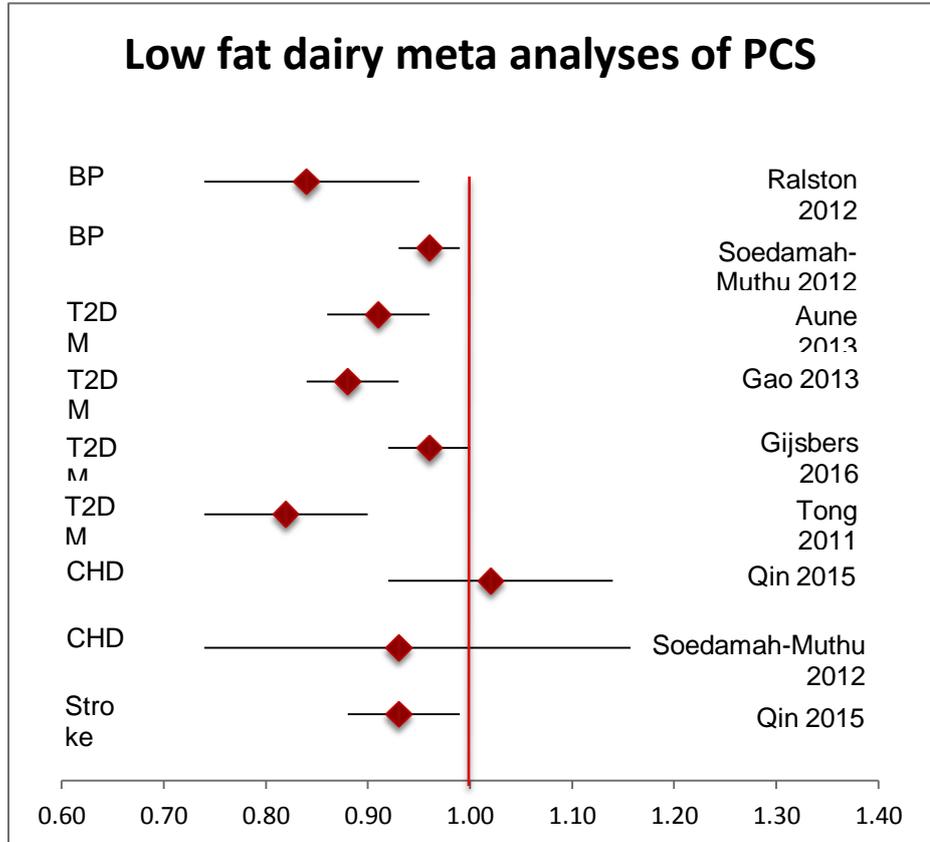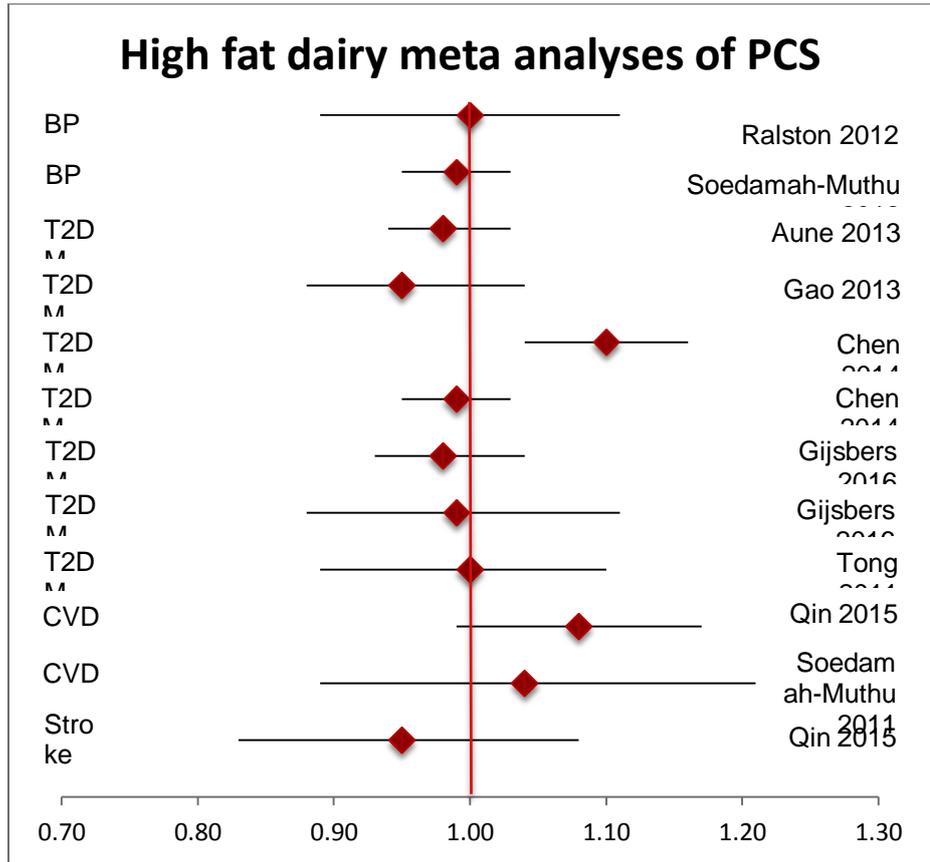
Summary

Overall, the data does not suggest an effect of dairy on inflammation.

SUMMARY

The graphs below summarise the risk estimates and 95% confidence intervals from meta-analyses of prospective cohort studies (described in the Appendix). Data left of the centre line signify associations with reduced risk and data right of the centre line are associations with increased risk. Error bars that cross the centre line signify a statistically non-significant finding. There is no weighting of the data presented. They do not show meta-analyses of RCTs as there were so few of them.

Meta-analyses can only be as good as the data they contain, and can hide faults in individual studies. Thus, while they provide a good summary of the current evidence they should still be interpreted in light of the whole evidence base.

High fat dairy meta analyses of PCS

Outcome	Study
BP	Ralston 2012
BP	Soedamah-Muthu 2012
T2DM	Aune 2013
T2DM	Gao 2013
T2DM	Chen 2014
T2DM	Chen 2014
T2DM	Gijsbers 2016
T2DM	Gijsbers 2016
T2DM	Tong 2011
CVD	Qin 2015
CVD	Soedamah-Muthu 2011
Stroke	Qin 2015

0.70 0.80 0.90 1.00 1.10 1.20 1.30

Low fat dairy meta analyses of PCS

Outcome	Study
BP	Ralston 2012
BP	Soedamah-Muthu 2012
T2DM	Aune 2013
T2DM	Gao 2013
T2DM	Gijsbers 2016
T2DM	Tong 2011
CHD	Qin 2015
CHD	Soedamah-Muthu 2012
Stroke	Qin 2015

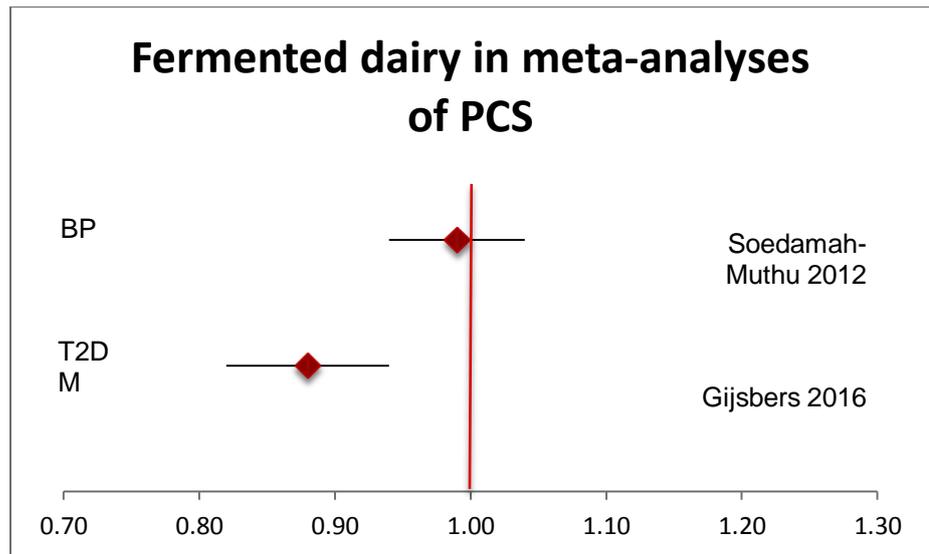0.60 0.70 0.80 0.90 1.00 1.10 1.20 1.30 1.40

Comparing the overall findings from meta-analyses of prospective cohort studies on high fat dairy and low fat dairy suggests:

- No statistically significant associations between high fat dairy and disease, except for one meta-analysis finding increased risk of type 2 diabetes. However, high fat dairy trended towards increased risk of CVD in both meta-analyses.
- Statistically significant associations between low fat dairy and reduced risk for hypertension, type 2 diabetes and stroke.
- It should be noted again that definitions of high and low fat dairy are not consistent between individual studies and meta-analyses.

Yoghurt in meta-analyses of PCS

	Effect (95% CI)	Study
BP		Ralston 2012
BP		Soedamah-Muthu 2012
T2DM		Aune 2013
T2DM		Gao 2013
T2DM		Chen 2014
T2DM		Gijsbers 2016
T2DM		Tong 2011

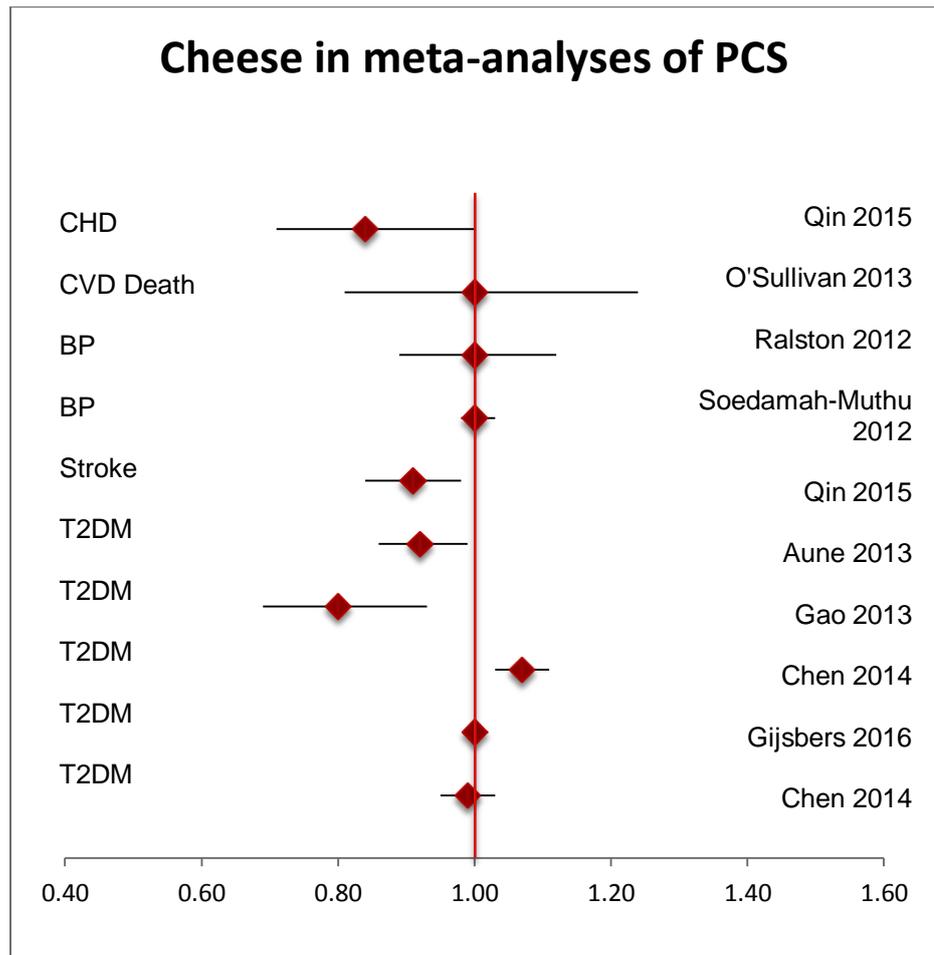| 0.50 | 0.70 | 0.90 | 1.10 | 1.30 | 1.50 |
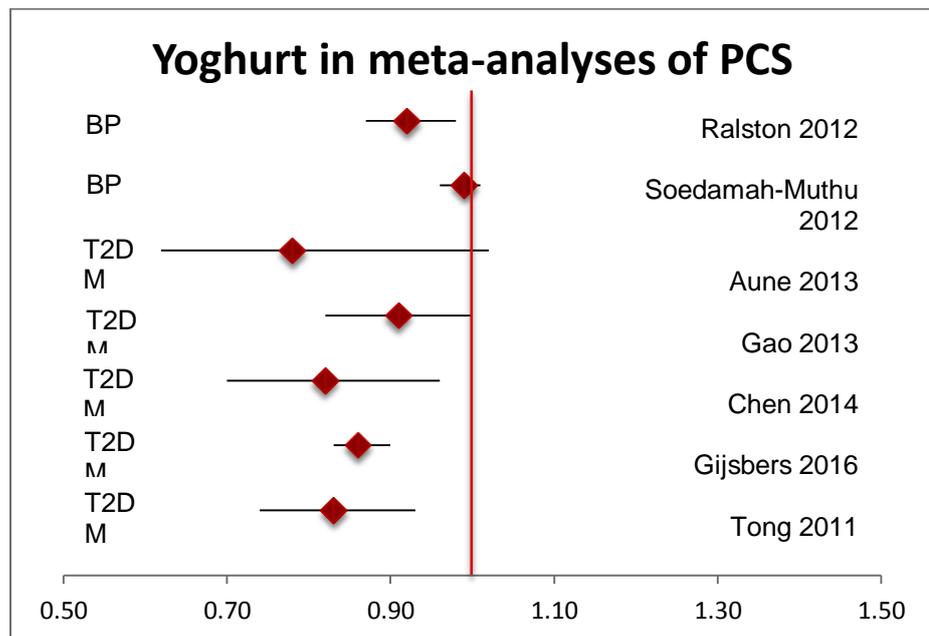
Comparing the overall findings from meta-analyses of prospective cohort studies on yoghurt suggests:

- No indication of increased risk of type 2 diabetes or hypertension from yoghurt consumption, and evidence for a decreased risk of type 2 diabetes and possibly decreased risk of hypertension.
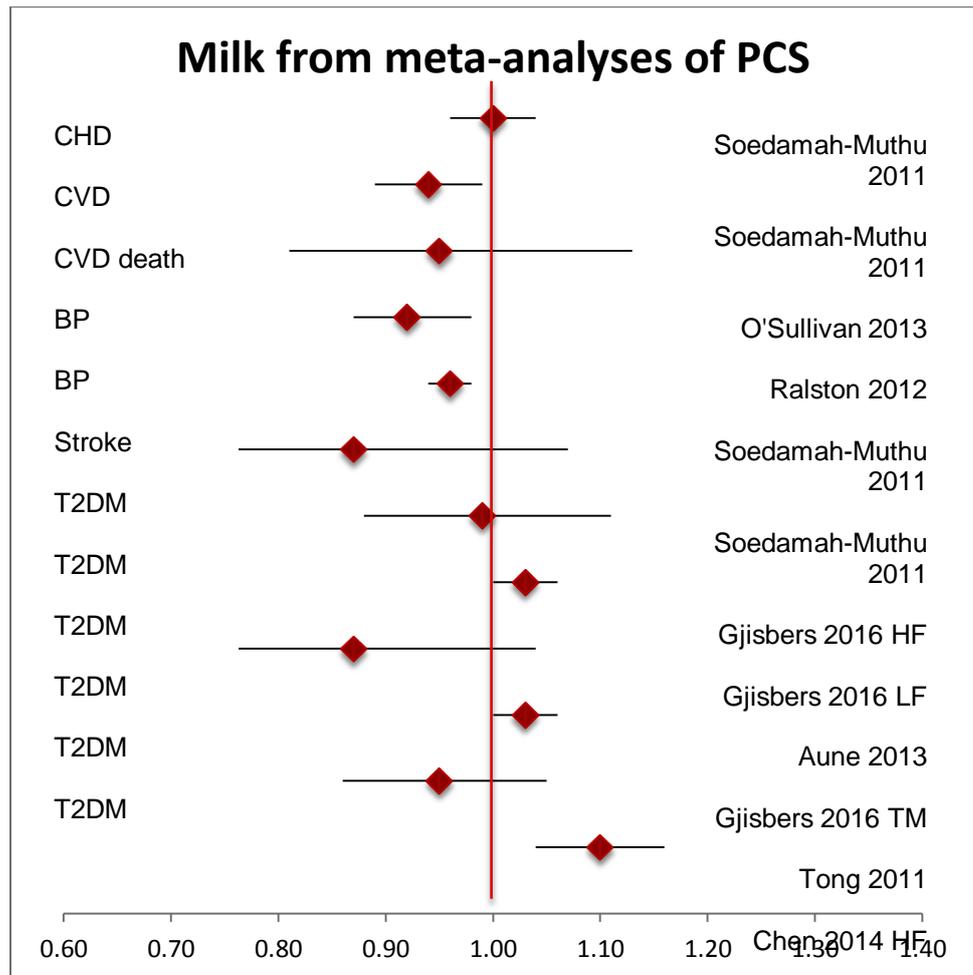
Fermented dairy in meta-analyses of PCS

There is limited data considering fermented dairy (yoghurt and cheese) as a group, but one meta-analysis shows an association with reduced risk of type 2 diabetes.

Interestingly, a Mendelian randomisation study found a higher intake of non-fermented milk was associated with increased all-cause mortality, while fermented milk and cheese were associated with lower risk. The increased risk with non-fermented milk was greater in full fat compared to low-fat milk.[165]

Cheese in meta-analyses of PCS

Comparing the overall findings from meta-analyses of prospective cohort studies on cheese suggests:

- Statistically significant associations between cheese and reduced risk of stroke (based on one meta-analysis) and type 2 diabetes, however the finding for type 2 diabetes is not a consistent finding across all meta-analyses.

Milk from meta-analyses of PCS

Condition	Study
CHD	Soedamah-Muthu 2011
CVD	Soedamah-Muthu 2011
CVD death	O'Sullivan 2013
BP	Ralston 2012
BP	Soedamah-Muthu 2011
Stroke	Soedamah-Muthu 2011
T2DM	Gjisbers 2016 HF
T2DM	Gjisbers 2016 LF
T2DM	Aune 2013
T2DM	Gjisbers 2016 TM
T2DM	Tong 2011
T2DM	Chen 2014 HF

Axis: 0.60 0.70 0.80 0.90 1.00 1.10 1.20 1.30 1.40

* HF = high fat; LF = low fat; TM = total milk

Comparing the overall findings from meta-analyses of prospective cohort studies on milk suggests a potential association with reduced risk of high blood pressure. Summaries of data on low-fat and full-fat dairy suggest this benefit is from low-fat milk. This is in contrast to a meta-analysis of RCTs that did not detect a significant effect of dairy or dairy fat on blood pressure over the shorter term.[84]

Finally, it is important to note that much of the research (primary research, reviews and individual researchers) on dairy has been funded by the dairy industry, and there has been a clear agenda to "neutralise the negative image of milk fat held by regulators and health professionals, specific to cardiovascular disease".[166] Funding disclosures and conflicts of interest are still not always published.

The only review that assessed the impact of funding source was the meta-analysis of RCTs by Benatar et al.[84] Industry funded (n=14) compared to publicly funded (n=6) studies had more favourable results for weight gain, waist circumference, HOMA-IR, LDL-cholesterol, HDL-cholesterol, C-reactive protein, systolic blood pressure, and diastolic blood pressure but not blood glucose. For five of these, industry compared to publicly funded studies had findings in opposite directions, with industry having favourable results and publicly funded having unfavourable results (waist circumference, HDL, CRP, SBP, DBP). Although none of the findings were statistically significant on their own, when combined into a meta-analysis they could influence the overall result.

CONCLUSION

This umbrella review suggests an overall neutral effect of dairy on cardiovascular risk for the general population. However, analyses by total dairy are a blunt tool that could disguise important differences between dairy products, and studies suggest there are differences. Studies also suggest that sex, age, or ethnic group could modify effects. None of the included reviews specifically looked at high-cardiovascular risk groups.

While overall it appears that total dairy is not harmful to heart health, a small number of substitution analyses have been conducted which consider replacement foods or nutrients. The analyses that have been conducted show associations with reduction in cardiovascular risk when dairy or dairy fat is replaced with options such as unsaturated fats or unrefined grains. Although limited in number, they have been consistent in their findings. This is in contrast to much of the data, which has produced inconsistent and mixed findings both within and between studies. Substitution analyses give recognition to the importance of the dietary context, rather than focusing on one food or nutrient on its own making a diet healthy or unhealthy. They are also important to consider when typical dietary patterns are known to have room for improvement, and the objective is to improve heart health rather than maintain the status quo. What this data suggests is that unsweetened milk, yoghurt and cheese can be included in a heart healthy eating pattern, but preferentially obtaining calories from unsaturated fats rather than dairy fat (eg. by choosing reduced fat options) is associated with reduced risk.

Some dairy foods were associated with beneficial effects on specific disease outcomes in prospective cohort studies. There was evidence for a beneficial association between yoghurt and type-2 diabetes and blood pressure; cheese and stroke; and between low-fat milk and blood pressure and possibly CVD, but not CHD. Yoghurt and cheese are both classified as fermented dairy.

The data of most relevance to this paper relates to whether reduced-fat dairy reduces cardiovascular risk in comparison to full-fat dairy. Data from high quality and adequately powered RCTs would be most informative to answer this question as they have a greater ability to isolate the effect of dairy fat by comparing low fat and full fat versions of the same food, without changing the overall diet. However, there is insufficient RCT data available and most are small studies with variable quality.

Whilst the evidence of high fat versus reduced fat dairy is inconsistent, observational data suggests reduced-fat is preferably associated with reduced risk of type 2 diabetes, hypertension, and possibly stroke. There appears little difference in observational studies in relation to inflammation, lipids and metabolic syndrome; and associations with a small potential benefit for full fat dairy on body weight, although this could be due to changes in refined carbohydrate intake. These findings are in contrast to RCTs which overall show benefits for reduced fat dairy over full fat on LDL cholesterol (no data on the effect on TC:HDL) and no difference between the two for body weight or hypertension. Interpretation of the data as it stands is hindered by different definitions of what counts as high fat and low fat dairy.

A recent expert review of the current status of nutrition and cardiovascular disease did not find any evidence in relation to dairy and cardiovascular disease that it could conclude was 'definitely known'.[25] The inadequacies in the evidence base preclude more confidence. There is inconsistency in findings both within and between studies, sometimes poor quality evidence, and the strong presence of vested interest. Despite the volume of research conducted, high-quality, adequately

powered, long-term and non-industry funded RCTs comparing full fat and reduced fat dairy products really are needed before recommendations can be made with more confidence. As it stands, the evidence overall supports that choosing reduced-fat dairy over full-fat reduces risk for some, but not all, cardiovascular risk factors.

Whilst there is some ambiguity around dairy fat, there is ample evidence that sources of fat that are part of a heart healthy eating pattern include nuts, oily fish, avocado, olives and most plant oils. These and other plant fats should be the predominant sources of fat in the diet. They are best consumed within a dietary pattern that emphasises vegetables and fruit, with unrefined grains, legumes, and, if eaten, non-processed lean meats, poultry and oily fish, and reduced fat yoghurt, milk and cheese.

OTHER RELEVANT HEART FOUNDATION EVIDENCE PAPERS

- Heart Foundation evidence paper on dietary patterns.
- Heart Foundation evidence paper on fats and fatty acids.

EVIDENCE TABLE 1: META-ANALYSES OF EPIDEMIOLOGICAL STUDIES ON DAIRY AND HEART DISEASE RISK

Study name and type	Population and dietary context	Intervention and comparator	Key outcomes	Other
Ralston 2012: meta-analysis of cohort studies[128]	5 cohorts with nearly 45,000 healthy participants (85% women) and 11,500 cases of raised blood pressure, published to April 2009. Follow up from 2 to 15 years.	Highest (691 to 757g total dairy intake) compared to lowest intake per day	*Elevated blood pressure* **Total dairy RR 0.87 (95% CI 0.81 to 0.94)** **Low-fat dairy RR 0.84 (95% CI 0.74 to 0.95)** High-fat dairy RR 1.00 (95% CI 0.89 to 1.11) **Milk/yoghurt RR 0.92 (95% CI 0.87 to 0.98)** Cheese RR 1.00 (95% CI 0.89 to 1.12)	Little heterogeneity, except for low-fat and high-fat dairy that had moderate heterogeneity.
Aune 2013: meta-analysis of cohort studies[139]	17 cohort studies (15 in dose-response analysis) (7 US, 6 Europe, 2 Asia, 2 Australia). For total dairy 426,066 participants and 26,976 cases of type 2 diabetes.	Dose-response: Total dairy per 400g/day High-fat dairy per 200g/day Low-fat dairy per 200g/day Milk per 200g/day Cheese per 50g/day Yoghurt per 200g/day	*Type 2 diabetes* **Total dairy RR 0.93 (95% CI 0.87 to 0.99)** High-fat dairy RR 0.98 (95% CI 0.94 to 1.03) **Low-fat dairy RR 0.91 (95% CI 0.86 to 0.96)** Milk RR 0.87 (95% CI 0.72 to 1.04) **Cheese RR 0.92 (95% CI 0.86 to 0.99)** Yoghurt RR 0.78 (95% CI 0.60 to 1.02)	Two EPIC studies were included despite overlap between them as they reported on different dairy food items. For total dairy, there was moderate heterogeneity. No evidence of publication bias. No increase in risk reduction after 300-400g/day total dairy. Sub-group analyses suggested inverse associations with total dairy and yoghurt were in US but not European populations.
Gao 2013: meta-analysis of cohort studies[138]	15 prospective cohort studies and 1 case-cohort study with 526,998 participants and 29,789 cases of type-2 diabetes (6, US, 6 Europe, 2 Asia, 2 Australia). Published 2005 to 2013.	Dose-response: Total, low and high fat per 200g/day Cheese per 30g/day Yoghurt per 50g/day	*Type 2 diabetes* **Total dairy RR 0.94 (95% CI 0.91 to 0.97)** **Low-fat dairy RR 0.88 (95% CI 0.84 to 0.93)** Full-fat dairy RR 0.95 (95% CI 0.88 to 1.04) **Cheese RR 0.80 (95% CI 0.69 to 0.93)** Yoghurt RR 0.91 (95% CI 0.82 to 1.00)	Quality assessment found overall moderate study quality. Inverse association with total and low-fat dairy was strongest at 200g/day. Total dairy inversely associated in US studies but not European or Asian studies. Dairy intake mostly assessed by FFQ.

Chen 2014: meta-analysis of prospective cohort studies[140]	14 prospective cohort studies on total dairy and six for yoghurt.	Dose response per 1 serving/day	*Type 2 diabetes* Total dairy RR 0.98 (95% CI 0.96 to 1.01) **Yoghurt RR 0.82 (95% CI 0.70 to 0.96)** **Cheese HR 1.07 (95% CI 1.03 to 1.11)** **Whole milk HR 1.10 (95% CI 1.04 to 1.16)** **Ice cream HR 0.78 (95% CI 0.71 to 0.86)** Cream HR 0.99 (95% CI 0.95 to 1.03)	Significant heterogeneity – decreased when two studies that did not adjust for total energy and other dietary confounders were excluded. These exclusions did not substantively change the risk estimates. No significant publication bias.
Elwood 2008: meta analysis of cohort studies[24]	15 prospective cohort studies on IHD and stroke; 4 case-control studies on MI	Highest vs lowest milk consumption	**MI: RR 0.83 (95% CI 0.66 to 0.99)** **IHD: RR 0.84 (95% CI 0.76 to 0.93)**	USDA rated this positive quality
Elwood 2010: meta analysis of prospective cohort studies[35]	Six cohort studies on dairy and all cause mortality; 9 studies on milk and IHD; 5 studies on milk and type 2 diabetes	Highest vs lowest dairy consumption	**All-cause mortality: RR 0.87 (95% CI 0.77 to 0.98)** **IHD: RR 0.92 (95% CI 0.80 to 0.99)** **Type 2 diabetes: RR 0.85 (95% CI 0.75 to 0.96)**	Studies used a variety of classifications for dairy and for intakes.
Qin 2015: meta-analysis of prospective cohort studies[27]	22 prospective cohort studies in adults (published 1997 to 2013, 10 in Europe, 5 in the US, 4 in Japan, 2 in Australia, 1 in Taiwan). Follow up from 8 to 26 years, with n=91,057 participants and 7,641 CVD cases.	Highest vs lowest dairy product consumption	*CVD* **Total dairy RR 0.88 (95% CI 0.81 to 0.96)** *CHD* Total dairy RR 0.94 (95% CI 0.82 to 1.07) High fat dairy RR 1.08 (95% CI 0.99 to 1.17) Low fat dairy RR 1.02 (95% CI 0.92 to 1.14) Cheese RR 0.84 (95% CI 0.71 to 1.00) *Stroke* **Total dairy RR 0.87 (95% CI 0.77 to 0.99)** High fat dairy: RR 0.95 (95% CI 0.83 to 1.08) **Low fat dairy: RR 0.93 (95% CI 0.88 to 0.99)** **Cheese RR 0.91 (95% CI 0.84 to 0.98)**	20 studies used a FFQ to assess dietary intake. No evidence of heterogeneity across studies for CVD, but evidence of heterogeneity for CHD and stroke. Little evidence of publication bias for CVD and CHD, but suggested publication bias for stroke.

| O'Sullivan 2013: meta-analysis of cohort studies[28] | 26 prospective cohort studies in adults (12 US, 7 Japan). Follow up from 5 to 41 years. | Highest vs lowest consumption | *All cause mortality*
Milk RR 1.01 (95% CI 0.92 to 1.11)
Cheese RR 1.03 (95% CI 0.97 to 1.09)
Butter RR 0.96 (95% CI 0.85 to 1.08)
All dairy RR 0.64 (95% CI 0.31 to 1.29)

CVD mortality
Milk RR 0.95 (95% CI 0.81 to 1.13)
Cheese RR 1.00 (95% CI 0.81 to 1.24)
All dairy RR 0.87 (95% CI 0.62 to 1.20)

CVD mortality with each additional serving per week
Milk (200mL) RR 1.00 (95% CI 0.99 to 1.01)
Cheese (40g) RR 1.01 (95% CI 0.99 to 1.02) | Non- or semi-quantitative FFQ used in 24 of the studies.

Substantial difference in level of adjustment for potential confounders.

Substantial heterogeneity between studies.

Most of the studies were graded low quality.

Little evidence of publication bias. |

Soedamah-Muthu 2011: meta-analysis of prospective cohort studies[32]	17 prospective cohort studies (5 US, 2 Japan, 10 Europe). 611,430 participants with a mean age of 56 years and mean BMI 25.	Dose-response, per serving of milk (200mL/day)	*All cause mortality* Milk RR 0.99 (95% CI 0.95, 1.03) *CVD* **Milk RR 0.94 (95% CI 0.89 to 0.99)** *CHD* Milk RR 1.00 (95% CI 0.96 to 1.04) Total dairy RR 1.02 (95% CI 0.93 to 1.11) High-fat dairy RR 1.04 (95% CI 0.89 to 1.21) Low-fat dairy RR 0.93 (95% CI 0.74 to 1.17) *Stroke* Milk RR 0.87 (95% CI 0.72 to 1.07)	All-cause mortality: significant between study heterogeneity. No evidence of publication bias. CVD: Inverse association in studies in men but not studies including men and women. Non-significant difference in studies that used full adjustment for confounding showed an inverse association between milk and CVD, whereas studies that did not showed no association. CHD: Non-significant differences found by US studies compared to European studies and sex. Data on dairy was based on a very limited number of studies. Updating the meta-analysis with data from the Nurses' Health Study on high vs low-fat dairy did not substantially change the results (high fat RR 1.05; low fat RR 1.01 both non-significant). Stroke: significant between study heterogeneity. Effect modification suggested for sex and degree of confounding (non-significant). In this review, most of the studies measured diet during the 1980s.

Soedamah-Muthu 2012: meta-analysis of prospective cohort studies[129]	Nine prospective cohort studies published to July 2011 (3 US, 6 Europe). Follow-up 2 to 15 years. Mean age 48 years.	Dose-response per 200g/day milk and total dairy; 30g/day cheese; 150g/day fermented dairy; 50g/day yoghurt.	*Hypertension* **Total dairy RR 0.97 (95% CI 0.95 to 0.99)** **Low fat dairy RR 0.96 (95% CI 0.93 to 0.99)** High fat dairy RR 0.99 (95% CI 0.95 to 1.03) **Milk 0.96 (95% CI 0.94 to 0.98)** Fermented dairy RR 0.99 (95% CI 0.94 to 1.04) Yoghurt RR 0.99 (95% CI 0.96 to 1.01) Cheese RR 1.00 (95% CI 0.98 to 1.03)	Total dairy: stratification by BMI showed a slightly stronger association with overweight. No significant heterogeneity. Most of the studies started in the 1990s. In the four earlier studies, high-fat milk was a major contributor to total milk intakes, whereas in the later studies it was more often low-fat milk.
Chen 2015: meta-analysis of observational studies[151]	15 cross sectional studies, one case-control study, seven prospective cohort studies. Cohort studies were published between 2002 and 2013 (2 USA, 5 Europe/Asia/ Australia).	High versus low dairy consumption Dose-response 1 serving/day	*Metabolic syndrome* **PCS RR 0.86 (95% CI 0.79 to 0.92)** **Cross-sectional/case-control studies OR 0.83 (95% CI 0.73 to 0.94)** **Dose-response RR 0.94 (95% CI 0.90 to 0.98)** at up to two servings/day.	Cohort studies no evidence for heterogeneity or publication bias. Most studies used self-reported FFQ to assess dietary intake. Classifications of dairy foods were inconsistent between studies. Types of dairy differed between population groups.

Kim 2016: meta-analysis of observational studies[150]	9 prospective cohort studies with 35,379 adults and 7,322 incident cases. 12 cross-sectional studies with 37,706 subjects (3 Europe, 3 US, 2 Asia, 1 Oceania). Follow up 2.8 to 10 years. Published to March 2015.	Highest versus lowest dairy intake Dose-response 1 serving/day	*Metabolic syndrome* **PCS RR 0.85 (95% CI 0.73 to 0.98)** **Cross-sectional studies RR 0.73 (95% CI 0.63 to 0.86)** **Dose-response RR 0.88 (95% CI 0.82 to 0.95)**	No difference by geographical region or length of follow up. Seven studies used a FFQ, one used a diet history, and one used a questionnaire (and reported dairy consumption as yes/no). Cohort studies had a mean quality score of 8.9 out of 13 (range 7-10). No significant heterogeneity. Sub-group analysis limited to studies that had adjusted for energy intake strengthened the overall relationship. Different criteria used to diagnose metabolic syndrome between studies. Few studies provided results by dairy fat or dairy type.

Gijsbers 2016: dose-response meta-analysis of prospective cohort studies[141]	22 studies (23 cohorts) published to April 2015 (9 US, 8 Europe, 3 Asia, 2 Australia). Mean age >36 years. Sample size 640 to 85,884. Follow up 2.6 to 30 years. Total dairy intake from 111g to 400g/day.	Dose-response per 200g/day total dairy or milk. Cheese per 10g/day. Yoghurt per 80g/day. Fermented dairy per 40g/day.	*Type 2 diabetes* **Total dairy RR 0.97 (95% CI 0.95 to 1.00, P=0.04)** Low fat dairy RR 0.96 (95% CI 0.92 to 1.00) High fat dairy RR 0.98 (95% CI 0.93 to 1.04) Total milk RR 0.97 (95% CI 0.93 to 1.02) Adjusted for major confounders RR 1.03 (95% CI 1.00 to 1.06) Low fat milk RR 1.01 (95% CI 0.97 to 1.05) Adjusted for major confounders RR 1.03 (95% CI 1.00 to 1.06) High fat milk RR 0.99 (95% CI 0.88 to 1.11) **US RR 1.11 (95% CI 1.03 to 1.20)** Fermented dairy RR 0.88 (95% CI 0.82 to 0.94) (but no dose response) Cheese RR 1.00 (95% CI 0.99 to 1.02) **Men RR 1.05 (95% CI 1.02 to 1.09)** Yoghurt RR 0.86 (95% CI 0.83 to 0.90) (but no dose response)	Quality scores ranged from 3 to 9, with 14 studies scoring >7 out of 13. Significant heterogeneity was present for all analyses (eg. I^2 = 66% for total dairy). No evidence of publication bias. For total dairy, total milk and low-fat milk studies that adjusted for major confounders had different results to those that did not. Sub-group analyses for European and Asian populations trended in opposite directions, with a reduced risk for Asian populations for total dairy and total milk. This may have been impacted by lack of adjustment for confounding. Sub-group analyses also showed an effect of length of follow up and age for some categories. There were differences by sex for cheese and yoghurt.
Tong 2011: dose response meta-analysis of prospective cohort studies[142]	7 studies (4 US, 2 Asia, 1 Europe). Mean age 39 to 57 years. Follow up from 5 to 20 years.	High versus low intake	*Type 2 diabetes* **Total dairy RR 0.86 (95% CI 0.79 to 0.92)** **Low fat RR 0.82 (95% CI 0.74 to 0.90)** High fat RR 1.00 (95% CI 0.89 to 1.10) Milk 0.95 (95% CI 0.86 to 1.05) **Yoghurt RR 0.83 (95% CI 0.74 to 0.93)**	No evidence of publication bias. Ambiguous definition of dairy in some studies. Small number of studies in some analyses.

Schwingshackl 2016: meta-analysis of prospective cohort studies[104]	22 studies in healthy adults with 76 to 120,077 participants (all except three in US and Europe). Follow up 9 to 23 years.	*Weight change (grams per year) per serving increase* Whole fat dairy 14.35g (95% CI-7.12 to 35.82) Low fat dairy -6.02g (95% CI -16.19 to 4.15) **Yoghurt -40.99g (95% CI -48.09 to -33.8)** Cheese 10.97g (95% CI 2.86 to 19.07) Dairy 11.56g (95% CI -13.55 to 36.67) *Waist circumference (cm per year) with high vs low intake* Total dairy -0.07cm/year (95% CI -0.09 to 0.01) *Risk of overweight* Total dairy RR 0.87 (95% CI 0.76 to 1.00) *Abdominal obesity* **Total dairy RR 0.85 (95% CI 0.76 to 0.95)** Low fat dairy RR 1.00 (95% CI 0.92 to 1.09) Whole fat dairy RR 0.83 (95% CI 0.64 to 1.07) **Yoghurt RR 0.81 (95% CI 0.71 to 0.92)**	All but four studies used FFQ for dietary assessment. Five studies used self-reported measures of body weight or waist circumference. Pooling studies was difficult due to differences in methods of assessing dairy exposure and adiposity outcomes, and statistical differences. Some studies only assessed baseline dairy consumption.
Dror 2014: meta analysis[106]	22 studies (12 US) in children and adolescents	*Adiposity* Dairy intake effect estimate = -0.07 (95% CI −0.32 to 0.18) Adolescents effect size -0.26 (95% CI -0.38 to -0.14) Not significant in school age or pre-school children	

EVIDENCE TABLE 2: META-ANALYSES OF INTERVENTION STUDIES ON DAIRY AND RISK FACTORS

Study name and type	Population and dietary context	Intervention and comparator	Key outcomes	Notes

Abargouei 2012: meta-analysis of RCTs[112]	14 RCTs in 883 adults aged 18-85 years. Most studies less than 12 weeks duration and in the US.	Effect of high versus low dairy intake on body weight, fat mass, lean mass, and waist circumference Five RCTs without energy restriction: Increased calcium by 400-850mg/day via dairy products compared to habitual diet Nine RCTs with energy-restricted high-dairy weight loss diets: additional calcium intake of 550-1000mg/day via dairy products compared to 290-800mg/day calcium. 500kCal energy deficit in both groups.	*High versus low dairy intake* Mean difference body weight -0.61 kg (95% CI -1.29 to 0.07) **Energy restricted -1.29kg (95% CI -1.98 to -0.6)** No energy restriction -0.33kg (95% CI -0.35 to 1.00) *Fat mass* Pooled estimated standard difference -0.72 kg (95% CI -1.29 to 0.14) Energy restricted -1.11kg (95% CI -1.75 to 0.047) No energy restriction -0.16kg (95% CI -0.97 to 0.66) *Lean mass* **Pooled estimated standard difference +0.58 kg (95% CI 0.18 to 0.99)** **Energy restricted +0.72kg (95% CI 0.12 to 1.32)** No energy restriction +0.35kg (95% CI -0.15 to 0.86) *Waist circumference* Pooled estimated standard difference -2.19 cm (95% CI -3.42 to 0.96) No energy restriction -2.68cm (95% CI -8.02 to 2.66)	
Benatar 2013: Meta-analysis of RCTs[84]	20 studies with 1677 healthy adults. Average age 51 years, 78% female. Median duration of follow-up 26 weeks.	Increase in dairy food, by a mean of 3.6 serves/day. Average difference in dairy intake was 3.12 serves/day.	*Weight*: **Increased dairy intake +0.50kg (95% CI 0.30 to 0.90)** **Low fat dairy +0.82kg (95% CI 0.35 to 1.28)** **Whole fat dairy +0.41kg (95% CI 0.06 to 0.79)** *Waist circumference* **Increased dairy -0.07cm (95% CI -1.24 to 1.10)** Low fat +1.18cm (95% CI -0.61 to 2.96) Whole fat -0.58cm (95% CI -1.99 to 0.83) *HOMA-IR*	Most included trials were small and modest quality. Similar weight gain in studies with overweight/obese and normal weight participants. Stratification by funding source showed more positive results for industry-funded research.

Increased dairy -0.94 units (95% CI -1.93 to 0.04)
Whole fat -0.63 (95% CI -1.50 to 0.24)

Fasting blood glucose
Increased dairy +1.32mg/dL (95% CI 0.19 to 2.45)
Low fat +0.83 (95% CI-0.78 to 2.43)
Whole fat +1.80 (95% CI 0.21 to 3.40)

LDL cholesterol
Increased dairy +1.85 mg/dL (95% CI -2.89 to 6.60)
Whole fat dairy +3.30mg/dL (95% CI -4.30 to 10.90)
Low fat dairy -1.42mg/dL (95% CI -4.74 to 1.91)

HDL cholesterol
Increased dairy -0.19mg/dL (95% CI -2.10 to 1.71)
Low fat +0.73mg/dL (95% CI -2.50 to 3.96)
Whole fat -0.69mg/dL (95% CI -3.04 to 1.67)

C-reactive protein
Increased dairy -1.07mg/L (95% CI -2.54 to 0.39)
Low fat -0.62 (95% CI -1.32 to 0.11)
High fat -1.81 (95% CI -5.47 to 1.84)

Systolic blood pressure
Increased dairy -0.41mmHg (95% CI -1.63 to 0.81)
Low fat -0.85 (95% CI -2.55 to 0.84)
Whole fat 0.07 (95% CI -1.69 to 1.83)

Diastolic blood pressure
Increased dairy -0.45mmHg (95% CI -1.70 to 0.80)
Low fat -0.43 (95% CI -1.68 to 0.82)
Whole fat -0.69 (95% CI -3.20 to 1.83)

Stratification by study length showed trials over six months had less favourable outcomes than those less than six months, except for diastolic blood pressure and waist circumference.

Chen 2012: pooled analysis of RCTs[110]	29 RCTs with 2101 adult participants published to April 2012 (17 US). 24 trials with overweight or obese participants. Median duration of four months.	Consumption of dairy products. Most studies had habitual diet or a calorie-restricted diet with lower dairy consumption as the control. Two studies used an isocaloric sucrose beverage or fruit juice.	*Body weight* -0.14kg (95% CI -0.66 to 0.38) **Energy restricted diets -0.79kg (95% CI -1.35 to -0.23)** No energy restriction 0.39kg (95% CI -0.36 to 1.13) *Body fat* **-0.45kg (95% CI -0.79 to -0.11)** **Energy restricted diets -0.94kg (95% CI -1.53 to -0.34)** No energy restriction -0.12kg (95% CI -0.71 to 0.46)	19 studies classified as high quality (a Jadad score of ≥3, as double blinding very difficult) and 10 studies were low quality. Significant heterogeneity for both body weight and body fat. Interventions of less than one year significantly reduced body weight and body fat, whereas interventions over one year increased weight and had no change in body fat. No significant publication bias.

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