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REVIEW

Dairy versus other saturated fats source and cardiometabolic risk markers: Systematic review of randomized controlled trials

Camila Duarte[a], Victória Boccardi[a], Patrícia Amaro Andrade[b*], Aline Cristine Souza Lopes[a], and Paul F. Jacques[c,d]

[a]Departament of Nutrition, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil; [b]Universidade Federal de Viçosa, Belo Horizonte, Brazil; [c]Friedman School of Nutrition Science and Policy, Tufts University, Boston, Massachusetts, USA; [d]Jean Mayer USDA Human Nutrition Research Center on Aging, Tufts University, Boston, Massachusetts, USA

ABSTRACT
To analyze the effects of dairy intake on cardiometabolic risk markers compared to other dietary fat sources in adults. Literature database and gray literature were searched for studies published up to October 2018. Two independent authors selected and extracted data from articles. Summary tables were constructed to present data for all outcomes. The intake of dairy appears to have a protective effect on some cardiovascular risk factors, or it is not worse than other SFA sources. The higher intake of dairy can decrease total cholesterol and reduce waist circumference and increase HDL cholesterol. However, it can also increase LDL and triglycerides, although those were small changes. It was observed that the effect of dairy on several serum lipids varied according to the type dairy product used on intervention. Dairy products seem to present a different effect on cardiometabolic risk factors than other fat sources, with evidence of improvement on metabolic parameters compared to another animal source of SFA.

KEYWORDS
cardiovascular diseases; dairy; dietary fat; metabolic syndrome; saturated fatty acids

Introduction

Cardiometabolic risk can be defined as a set of conditions that favor the development of type 2 diabetes mellitus (DM) and Cardiovascular disease (CVD). CVD is the leading cause of death globally and it is estimated that 31% of the world's deaths are related to this disease (World Health Organization 2017), being ischemic heart disease the leading cause of disability-adjusted life years (DALYs) (Global Health Estimates 2016, 2018). Diabetes alone does not cause mortality, but rather its related complications. It was ranked 12 in the causes of DALYs in 2000 and has since moved up to 8 th position in 2016 (Global Health Estimates 2016 2016, 2018). Both diseases have a significant impact on the finances, well-being and quality of life of patients.

The relationship between dietary macronutrient composition and cardiometabolic dysfunction is widely studied in the literature (Fleming and Kris-Etherton 2016; Jacome-Sosa et al. 2016). Current guidelines give more emphasis on the quality of fat, proportion of saturated and unsaturated lipids, than the amount of fat intake. On the last decades saturated fatty acids (SFA) has turned from foe to friend and vice-verse, and is still a controversial issue. Meta-analysis of 15 randomized controlled trials with 59,000 participants evidenced that a reduction of total SFA intake has been accompanied to a small but important reduction in cardiovascular risk (Hooper et al. 2015). On the other hand, the PURE study, which included over 100,000 people from 18 countries found that diets high in SFA were not associated with cardiovascular disease events, except for a lower risk of stroke (Dehghan et al. 2017). Reevaluation of the Minnesota Coronary Experiment evidenced no reduction in coronary heart disease and death with the replacement of SFA by vegetable oil rich in linoleic acid, although a lowering effect was observed in LDL cholesterol (Ramsden et al. 2016).

Another important factor is the dietary sources of SFA. A cross-sectional study indicated that red meat SFA (Duarte et al. 2018) appears to be associated with the highest percentage of body fat in type 2 diabetes. On the other hand, dairy and yogurt intake was associated with a smaller increase in weight and waist circumference according to a 13-year follow-up of the Framingham Heart Study offspring cohort (Wang et al. 2014). Total and especially full-fat dairy food intakes were inversely and independently associated with metabolic syndrome in a multicenter cohort study with 9,835 middle-aged and older adults and this associations seemed to be mediated by dairy SFA (Drehmer et al. 2016). The specific role of different sources of SFA in cardiometabolic risk is still uncertain and SFA from dairy products may have a different role.

Different types of SFA have different effects on health. SFA can present short (1-6 saturated carbons), medium (7–12 saturated carbons) or long chains (13 or more saturated carbon). For example, medium chain SFA are

CONTACT Camila Duarte camila.kummel@gmail.com Universidade Federal de Minas Gerais, Belo Horizonte 30130-100, Brazil.
*Present address: Hospital de Clínicas da Universidade Federal de Minas Gerais.
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associated with higher HDL cholesterol (Panth et al. 2018) compared to long chain SFA. Another important property of SFA is their oxidation rate, which varies according to type and length. DeLany et al. (DeLany et al. 2000) observed a greater oxidation rate of lauric acid (12:0) compared to stearic acid (18:0) and palmitic (16:0). Some cross-sectional studies observed that body fat distribution was dependent on the proportion and type of SFA: palmitic fatty acid (16:0) was associated with abdominal adiposity (Yu et al. 2012), visceral adipose tissue thickness (Kishino et al. 2008) and total obesity (Garaulet et al. 2011). However, long chain SFA, like palmitic (16:0) and stearic (18:0) fatty acids are endogenously synthesized, affecting the proportion of circulating SFA.

Considering the exposed, we hypothesized that a diet with dairy products may have a neutral or reducing effect on cardiometabolic risk factors compared to a diet with none or less dairy products but with the same amount of SFA. Our aim is to systematically review the literature to evaluate the effects of dairy intake on cardiometabolic risk markers compared to other dietary SFA sources in adults.

Methods

We carried out a systematic review of randomized clinical trials that evaluated the consumption of dairy SFA on cardiometabolic risk markers in adults. This systematic review is reported according to the PRISMA Statement (Moher et al. 2009) and was conducted following the recommendations of the Cochrane Handbook for Systematic Reviews of Interventions (Higgins and Green 2011). In January 2019, we selected all randomized clinical trials studies meeting the eligibility criteria for this paper. This review was registered in the international prospective register of systematic reviews PROSPERO network (registration no. CRD42019111832).

Search strategy

Searches were performed with the use of SCOPUS, MEDLINE (via PubMed), EMBASE, WEB OF SCIENCE, CENTRAL COCHRANE, SCIELO, related articles, hand-searching of reference lists, and direct author contact. Besides, bases of unpublished articles and thesis bases were also used as sources of articles. No period or language restrictions were used in the search strategy. Key words were dairy products, saturated fat, fatty acids, dietary fats, metabolic syndrome, lipids, arterial pressure, hypertension, dyslipidemias and body mass index. The following search strategy was used in PubMed: ((((((((“Fatty Acids”[Mesh] OR “Fatty Acids” OR “Acids, Fatty” OR “Fatty Acids, Esterified” OR “Acids, Esterified Fatty” OR “Esterified Fatty Acids” OR “Fatty Acids, Saturated” OR “Acids, Saturated Fatty” OR “Saturated Fatty Acids” OR “Aliphatic Acids” OR “Acids, Aliphatic”))) OR ((“Saturated fat” OR “saturated fatty acids” OR “Fatty Acids, Saturated”)))) AND ((“Adult”[Mesh] OR “Adult”[Mesh] OR “Adults”))) AND ((“Dairy Products”[Mesh] OR “Dairy Products” OR “Dairy Product” OR “Product, Dairy” OR “Products, Dairy”)))) AND (((randomized controlled trial[pt] OR controlled clinical trial[pt] OR randomized controlled trials[mh] OR random allocation[mh] OR double-blind method[mh] OR single-blind method[mh] OR clinical trial[pt] OR clinical trials[mh] OR (“clinical trial”[tw]) OR ((singl*[tw] OR doubl*[tw] OR trebl*[tw] OR tripl*[tw]) AND (mask*[tw] OR blind*[tw])) OR (“latin square”[tw]) OR placebos[mh] OR placebo*[tw] OR random*[tw] OR research design [mh:noexp] OR comparative studies[mh] OR evaluation studies[mh] OR follow-up studies[mh] OR prospective studies[mh] OR cross-over studies[mh] OR control*[tw] OR prospectiv*[tw] OR volunteer*[tw]) NOT (animal[mh] NOT human[mh])))).

Eligibility criteria

We included only randomized controlled trials in which cardiometabolic risk markers (weight, BMI, body fat percentage, TC, LDL-c, HDL, TG, glycemia, systolic and diastolic blood pressures, including postprandial result) were evaluated in adults after intervention with dairy products or other sources of SFA in the same amount of percentage of energy. Studies that compared high and low dairy intake were included only if the control group and intervention consumed the same percentage of calories in the form of SFA. We excluded, a priori, case-control studies, cohort or ecological studies, commentaries, general reviews, case reports, animal studies or studies conducted on subjects other than adults. We also excluded, a priori, dairy products from other animals instead of cows. We excluded studies comparing different amounts of SFA in their interventions and studies in which the intervention and control group consumed SFA from the same food group, e.g. cheese versus milk.

Study selection, data-collection process, and data items

The title and abstracts were read in duplicate by two investigators (CKD and VBB) to check for eligibility criteria, with differences resolved by consensus. The software ENDNOTE X9 was used to read titles and abstracts. For abstracts from congress and symposia, authors were contacted for information about recent publications or information about those data.

Data was extracted independently and in duplicate by two investigators (CKD and VBB), including the year when the study was performed and reported, study design, sample size, type of population studied, cardiometabolic risk markers outcomes [weight, body mass index (BMI), body fat percentage, total cholesterol (TC), LDL, HDL, triglycerides (TG), glycemia, systolic and diastolic blood pressures] duration of follow-up and adjusted risk estimates and confidence intervals or mean and standard deviation in the lowest and highest percentile of dairy intake. When a multivariable model was reported, risk estimates with the greatest control for potential confounders were extracted.

Risk of bias within and across studies

The Cochrane Collaboration’s revised tool (Higgins et al. 2016) to assess the risk of bias in randomized trials (RoB 2.0) was used for the quality assessment of studies. Two authors (CKD and PAA) evaluated the risk of bias. The RoB 2.0 contains assessment for individually randomized trials in five domains: randomization process, deviations from intended interventions, missing outcome data, and measurement of the outcome and selection of the reported result. Differences in quality assessment scores between investigators were unusual and were solved by consensus.

Results

We conducted a systematic search of the literature and found 2949 citations. Of these 538 were duplicates and 2337 were abstracts, leaving 77 full text citations. Out of these, only 13 (Smilowitz et al. 2011; Khaw et al. 2018; Kris-Etherton et al. 1993; Park et al. 1996; Drouin-Chartier et al. 2015; Sørensen et al. 2014; Thorning et al. 2015; Abdullah et al. 2015; Crichton et al. 2012; Demmer et al. 2016; Hilpert et al. 2009; Nguo et al. 2018; Wennersberg et al. 2009) Randomized Clinical Trials (RCT) meeting our eligibility criteria were included in the systematic review (Figure 1). Two articles were parallel RCT (Khaw et al. 2018; Wennersberg et al. 2009) and 11 (Smilowitz et al. 2011; Kris-Etherton et al. 1993; Park et al. 1996; Drouin-Chartier et al. 2015; Sørensen et al. 2014; Thorning et al. 2015; Abdullah et al. 2015; Crichton et al. 2012; Demmer et al. 2016; Hilpert et al. 2009; Nguo et al. 2018) had crossover design with washout period.

All the RCTs evaluated dairy products intake and their effects on cardiometabolic risk markers, including BMI, weight, body fat percentage, waist circumference, lipid profile and blood pressure. Milk, yogurt, cheese and butter were used as dairy products for the interventions. The studies evaluated 656 participants with mean age varying from 23.8 to 59.9 years old, as shown in Table 1. Studies were conducted in North America (n = 7), Europe (n = 4) and Australia (n = 2).

In each RCT, the amount of SFA in the intervention and control groups was similar and the quantity varied substantially between studies (7 to 22.9% of total energy). Participants consumed less than 10% of SFA from total energy in 3 studies, and over 10% in 10 studies. Macronutrient composition in intervention and control group varied from 39% to 57.8%, 7.1% to 24.1% and 28% to 50.8% for carbohydrates, protein and fat, respectively. Except for the study of Abdulhah et al. (Abdullah et al. 2015), the proportion of each macronutrient was balanced between intervention and control groups.

Body composition

The efficacy of the dairy interventions on body composition in each of the selected RCT are summarized in Table 2. Eight RCT evaluated the effect of dairy on weight. The changes on weight were similar in the interventions with dairy as the main source of SFA compared to the other sources. However, the amplitude of change caused by dairy was smaller. Likewise, the intervention with dairy products had small effect on BMI and it was similar to other SFA sources. Four studies (Smilowitz et al. 2011; Khaw et al. 2018; Crichton et al. 2012; Wennersberg et al. 2009) reported body fat percentage estimates for the comparison of dairy and other SFA sources. Body fat was measured with bioelectrical impedance in one study (Khaw et al. 2018) and with dual energy X-ray absorptiometry on the other three (Smilowitz et al. 2011; Crichton et al. 2012; Wennersberg et al. 2009). One trial found a significant reduction in body fat percentage with dairy intervention, but after the multivariable analysis it lost its statistical significance (Smilowitz et al. 2011). In this trial, participants consumed less than 10% of energy on SFA (Smilowitz et al. 2011) and no effect was seen in trials where participants had an intake above the recommendation of 10% of energy as SFA (Khaw et al. 2018; Crichton et al. 2012; Wennersberg et al. 2009).

Five crossovers (Smilowitz et al. 2011; Drouin-Chartier et al. 2015; Abdullah et al. 2015; Crichton et al. 2012) and two parallel trials (Khaw et al. 2018; Wennersberg et al. 2009) assessing the effect of dairy on waist circumference were selected. Although no difference was observed between the interventions with dairy compared to other SFA source, in the trials in which participants had a low baseline BMI ($\leq$30 Kg/m^2) the reduction in WC was greater with dairy intake compared to those in trials with a higher baseline BMI ($>$30/kg/m^2) (Drouin-Chartier et al. 2015; Crichton et al. 2012; Wennersberg et al. 2009).

Lipid profile

The effect of the dairy intervention on lipid profile variables are summarized in Table 3. Ten articles provided comparisons of dairy with other SFA sources on serum lipids like TC, LDL cholesterol, HDL cholesterol and TG. Nine studies provided estimates for the relationship between dairy products and TC. Except for two RCT (Drouin-Chartier et al. 2015; Abdullah et al. 2015), dairy intake increased TC or had a neutral effect. When increase was observed in both, intervention and control groups, the TC change was greater with dairy intervention. However, in the two studies in which dairy reduced TC, the reduction for TC for dairy was smaller compared to the other SFA sources. The type of dairy used as the intervention resulted in different effects. For butter, there was an increasing trend for TC (Khaw et al. 2018; Kris-Etherton et al. 1993; Park et al. 1996) whereas no trend was observed in studies using general dairy products like milk, cheese and yogurt. Also, the effect size depended on the type of SFA source used as comparator for dairy, such as saturated vegetable fat or nondairy saturated animal fat. Four studies observed an increase in TC after dairy intake (Khaw et al. 2018; Kris-Etherton et al. 1993; Park et al. 1996; Abdullah et al., 2015) compared to vegetable fat rich in SFA, like palm oil and coconut oil. When the comparator was animal fat, there was a smaller increase (Park et al. 1996; Sørensen et al. 2014) effect or even a reduction (Drouin-Chartier et al. 2015; Thorning et al. 2015) on TC with the dairy intervention.

Nine studies accessed the relationship between dairy products and LDL. With the exception of the Thorning et al. (Thorning et al. 2015) trial, dairy interventions

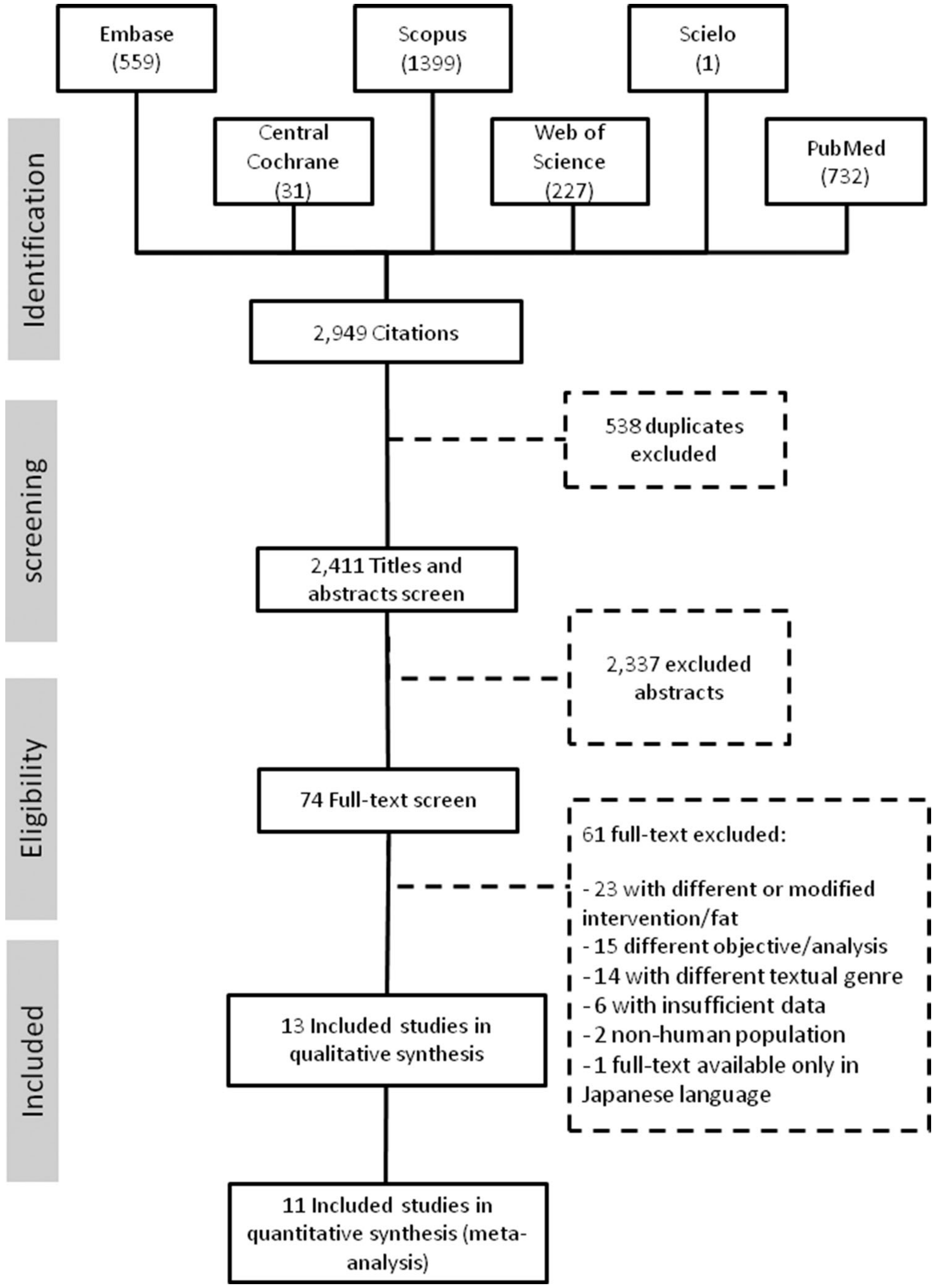

Figure 1. Flow chart of the selection process (October 31, 2018).

increased LDL, but the observed effect depended on the different type of dairy. Butter (Khaw et al. 2018; Kris-Etherton et al. 1993) was associated with a greater increase on LDL than other dairy products. As with the TC result, an increasing trend for LDL-c was observed when vegetable fat rich in SFA was used as the control for dairy (Khaw et al. 2018; Park et al. 1996; Abdullah et al. 2015); whereas a decreasing trend for LDL was observed when comparator was nondairy animal fat (Park et al. 1996; Drouin-Chartier et al. 2015; Sørensen et al. 2014; Thorning et al. 2015), like lard and red meat. The same nine studies, cited for TC and LDL-c, tested the effect of dairy intake on the HDL-c. Most trials showed a neutral or a small change effect on HDL with no difference compared to control group.

Ten studies evaluated the effect of dairy products on TG. The intake of dairy tended to raise TG in three (Sørensen et al. 2014; Crichton et al. 2012; Demmer et al. 2016) trials, and decrease it in two (Drouin-Chartier et al. 2015; Abdullah et al. 2015) and have no effect in the other five trials (Khaw et al. 2018; Park et al. 1996; Thorning et al. 2015; Nguo et al. 2018; Wennersberg et al. 2009). The effect of dairy on TG was not different from other SFA sources in any of these trials. Two studies with acute tests based on a single meal intervention showed similar results for triglycerides (Demmer et al. 2016; Nguo et al. 2018). In the first study, the concentration of plasma triglyceride was similar after consumption of different sources of SFA, including dairy (Demmer et al. 2016). In the second one, the authors

Table 1. Main results for body composition.

Author et al., year	Study design	Population baseline characteristics	Country	Age (years ± sd or range)	n	Follow-up	Intervention (SFA main source)	Control	SFA in IG	SFA in CG
Abdullah et al. (2015)	RCT crossover	Healthy adults (32.3% of men) Mean WC: 87.5 ± 13.84 Mean BMI: 25.68 ± 4.28	Canada	39.3 ± 16.4	137	4 weeks	Dairy (low-fat milk, yogurt and cheddar cheese)	Control (cashews and cookie)	8.5%	10.7%
Crichton et al. (2012)	RCT crossover	Overweight and obese adults (women and men) Mean WC: 98.6 ± 14.6 Mean BMI: 32.1 ± 5.67	Australia	18 to 75	71	24 weeks	Low-fat dairy (>4 serves/day: milk, yogurt and custard)	Reduced dairy (≤1 serve/day: milk, yogurt and custard)	12.8%	12.9%
Demmer et al. (2016)	RCT crossover	Overweight and obese (35% of men) Mean WC: NA Mean BMI: NA	United States	49 ± 11	20	6 hours	Cheese (Cheddar Cheese)	Vegan alternative (vegan cheese with coconut oil)	16.8%	17.2%
Drouin-Chartier et al. (2015)	RCT crossover	Postmenopausal women with abdominal obesity Mean WC: 102.3 ± 8.05 Mean BMI: 31.3 ± 3.37	Canada	57 ± 5	29	6 weeks	Milk (milk with 2% fat)	NCEP diet (red meat and egg)	9.8%	9.4%
Hilpert et al. (2009)	RCT crossover	Stage 1 hypertensive adults (69.6% of men) Mean WC: NA Mean BMI: NA	United States	43.5 ± 9.59	23	5 weeks	Dairy (3.4 servings/d of dairy)	Fruits and vegetable (vegetable fats)	7.0%	7.0%
Khaw et al. (2018)	RCT parallel	Healthy men and women (33% of men) Mean WC: 85.79 Mean BMI: 25.12	United Kingdom	59.9 ± 6.1	96	4 weeks	Butter	Coconut oil	13.3/ 14.1%	13.4%
Kris-Etherton et al. (1993)	RCT crossover	Healthy young men Mean WC: NA Mean BMI: NA	United States	26	33	3.7 weeks	Butter	Cocoa butter	21%	20.9%
Nguo et al. (2018)	RCT crossover	Healthy overweight men Mean WC: NA Mean BMI: NA	Australia	23.8 ± 1.4	13	NA	short/medium chain SFA (creams: milk, coconut and cheese)	long chain SFA (Palm olein, beef dripping)	22.95%	22.36%
Park et al. (1996)	RCT crossover	Healthy men Mean WC: NA Mean BMI: NA	United States	21 to 32	18	4 weeks	14:0 + 16:0 (butter)	12:0 + 14:0 (palm oil) 16:0 + 18:0 (lard + shea nut butter + coconut oil)	15%	15%
Smilowitz et al. (2011)	RCT crossover	Overweight and mildly obese adults (18% of men) Mean WC: 82.33 ± 9.27 Mean BMI: 27.5 ± 2.69	United States	24.9 ± 4.9	61	12 weeks	Dairy (milk, cheese, and/or yogurt)	control (≥1 serve of dairy products/day)	11.5%	9.2 and 9.8 %
Sørensen et al. (2014)	RCT crossover	Young and healthy men Mean WC: NA Mean BMI: NA	Denmark	27.7 ± 4.8	15	2 weeks	Milk or Cheese	nondairy diet (meat)	19.5/18.9%	18.6%
Thorning et al. (2015)	RCT crossover	Overweight postmenopausal women Mean WC: NA Mean BMI: NA	Denmark	59.0 ± 7.4	19	2 weeks	Cheese	Meat diet (high-fat processed and unprocessed meat)	17.9%	18.1%
Wennersberg et al. (2009)	RCT parallel	Overweight subjects with metabolic syndrome (33.8% of men) Mean WC: 100.55 ± 9.58 Mean BMI: 30 ± 3.44	Finland/ Norway/ Sweden	54,9 ± 8.0	121	24 weeks	Milk	Control (habitual diet without any dairy products)	14.3%	12.4%

RCT: Randomized Controlled Trial; WC: waist circumference; BMI: body mass index; SFA: saturated fatty acids; IG: intervention group; CG: control group; TC: total cholesterol; NCEP: National Cholesterol Education Program; HDL: high density lipoprotein cholesterol; LDL: low density lipoprotein cholesterol; TG: triglycerides; SBP: systolic blood pressure; DBP: diastolic blood pressure; BMI: body mass index; VS: versus; NA: not available.

Table 2. Main results for body composition.

Author, year	Main result	Systematic review conclusions
Body weight (kg)		
Abdullah et al. (2015)	There was no statistically significant difference in weight between the diets.	Weigh change (increase or reduction) was similar between the SFA sources
Crichton et al. (2012)	Both interventions increased body weight. However, the mean changes in body weight within the dairy phase were greater than within the low dairy phase.	Total change was smaller with dairy
Drouin-Chartier et al. (2015)	Both interventions reduced body weight, but the NCEP diet reduced more.	
Khaw et al. (2018)	There were no significant differences in changes in weight among any of the intervention groups.	
Smilowitz et al. (2011)	Significant reductions in weight was found among all dietary treatment groups, but after adjustments for protein, energy intakes and physical activity these relationships were no longer significant.	
Sørensen et al. (2014)	There was no statistically significant difference in anthropometric measurements between the diets.	
Thorning et al. (2015)	Body weight did not differ significantly between the 3 diets.	
Wennersberg et al. (2009)	Body weight remained unchanged during the intervention.	
Body mass index (Kg/m^2)		
Abdullah et al. (2015)	There was no statistically significant difference in BMI between the diets.	BMI change (increase or reduction) similar between the SFA sources.
Crichton et al. (2012)	There was no significant difference in BMI between diets, but the mean increase in BMI within the high dairy phase were greater than within the low dairy phase.	
Drouin-Chartier et al. (2015)	Both interventions reduced BMI, but the NCEP diet reduced more.	
Khaw et al. (2018)	There were no significant differences changes in BMI among any of the three intervention groups.	
Smilowitz et al. (2011)	Significant reductions in BMI was found among all dietary treatment groups. However, these relationships were no longer significant after adjustments for protein and energy intakes and physical activity.	
Wennersberg et al. (2009)	BMI remained unchanged during the intervention.	
Body fat (%)		
Crichton et al. (2012)	Dairy increased body fat but there was no significant difference between the high dairy and low dairy phases of the study.	Small effects on body fat percentage, most non-significant.
Khaw et al. (2018)	Dairy increased body fat percentage but there were no significant differences in change among any of the 3 diets.	
Smilowitz et al. (2011)	Dairy was found to be significantly associated with reduced %BF. However, these relationships were no longer significant after adjustments for protein and energy intakes and physical activity.	
Wennersberg et al. (2009)	Dairy reduced body fat percentage with no difference from control groups.	
Waist circumference (cm)		
Abdullah et al. (2015)	Dairy reduced WC but there was no statistically significant difference in measurement between the diets.	Small reductions on waist circumference related with the baseline BMI.
Crichton et al. (2012)	High dairy intake increased WC with no significant difference from the effect observed in low dairy phases of the study.	
Drouin-Chartier et al. (2015)	NCEP diet reduced waist circumference and dairy did not make any change.	
Khaw et al. (2018)	The diets increased WC, but dairy diet had a smaller effect although there were no significant differences among any of the groups.	
Thorning et al. (2015)	WC did not differ significantly between the 3 diets.	
Smilowitz et al. (2011)	Significant reduction in WC was found among all dietary treatment groups. However, these relationships were no longer significant after adjustments for protein and energy intakes and physical activity.	
Wennersberg et al. (2009)	WC reduced on both diets with no difference on milk effect compared to the control group.	

BMI: body mass index; NCEP: National Cholesterol Education Program.

reported that, after meals with either dairy (cream, full cream milk powder, coconut cream, cream cheese) or nondairy (palm oil, beef dripping) SFA, plasma triglycerides triglycerides concentration rose gradually with no difference between the dairy and no dairy meals over a 6 hour postpandial period (Nguo et al. 2018).

Blood pressure and glycemia

In total, eight studies evaluated the association between dairy intake and blood pressure or glycemia are described in Table 4 (Khaw et al. 2018; Drouin-Chartier et al. 2015; Sørensen et al. 2014; Abdullah et al. 2015; Crichton et al. 2012; Hilpert et al. 2009; Wennersberg et al. 2009). These studies shown a decreasing trend in blood pressure with dairy intake, and in some studies this associations was linked to the calcium intake increase (Hilpert et al. 2009). Eight studies also examined the effect of dairy on fasting blood glucose concentrations (Smilowitz et al. 2011; Khaw et al. 2018; Drouin-Chartier et al. 2015; Sørensen et al. 2014; Thorning et al. 2015; Crichton et al. 2012; Demmer et al. 2016; Wennersberg et al. 2009), but no effect of dairy interventions was observed on fasting blood glucose relative to other SFA sources. In two studies (Drouin-Chartier et al. 2015; Thorning et al. 2015) fasting glucose reduced, but similarly to other SFA sources.

Risk of bias

The overall risk of bias of the randomized controlled trials varied from low to high (Smilowitz et al. 2011; Khaw et al. 2018; Kris-Etherton et al. 1993; Park et al. 1996; Drouin-Chartier et al. 2015; Sørensen et al. 2014; Thorning et al.

Table 3. Main result for lipid profile.

Author, year	Main result	Systematic review Conclusions
Total cholesterol (mmol/L)		
Abdullah et al. (2015)	Dairy and control diets reduced total cholesterol with no difference between diets.	Dairy had a neutral effect or reduced TC The increase in TC was dependent on the SFA source: butter had a greater effect compared to other dairy Type of SFA source used as comparator influenced the differences observed
Crichton et al. (2012)	No significant changes.	
Drouin-Chartier et al. (2015)	Reduction in total plasma cholesterol concentrations was statistically more important after the NCEP diet than after the MILK diet (between-diet $P = 0.01$).	
Khaw et al. (2018)	Butter and coconut oil increased total cholesterol, but butter had a greater effect.	
Kris-Etherton et al. (1993)	The butter diet was hypercholesterolemic compared with all other experimental diets (coconut oil, olive oil and soybean oil).	
Park et al. (1996)	Dietary treatment did not affect TC in the subjects analyzed as a whole and stratified according to apo E phenotype.	
Sørensen et al. (2014)	All 3 diets increased total cholesterol compared with baseline. Compared with the control diet, the milk diet and the cheese diet attenuated the increase in total cholesterol. The magnitude of effect for milk tended to be smaller than for cheese but did not differ.	
Thorning et al. (2015)	Dairy reduced TC with no significant difference from the control diet.	
Wennersberg et al. (2009)	There was a significant increase in TC ($P = 0.043$) in the milk group. Regression analyses showed that the increase in serum cholesterol was significantly related to that of 15:0 ($r = 0.24$, $P = 0.011$), which suggests that the increased cholesterol concentrations were in fact due to the increased intake of milk fat.	
LDL cholesterol (mmol/L)		
Abdullah et al. (2015)	Dairy increased more the LDL cholesterol compared to control diet.	Dairy increased LDL The increase in LDL was dependent of the SFA source used: butter had a greater effect compared to other dairy products If comparator was a vegetable oil, increase in LDL with dairy was more evident
Crichton et al. (2012)	There was no significant change in LDL cholesterol.	
Drouin-Chartier et al. (2015)	Consumption of the milk diet had no impact on plasma LDL, and it was not different from the NCEP diet effect.	
Khaw et al. (2018)	Butter increased LDL and coconut slightly reduced.	
Kris-Etherton et al. (1993)	The butter diet increased LDL cholesterol compared to coconut diets with no statistical difference.	
Park et al. (1996)	Both diets increased LDL with no significant difference between them.	
Thorning et al. (2015)	There were no significant differences between diets in LDL cholesterol, although both reduced it.	
Sørensen et al. (2014)	All 3 diets increased LDL cholesterol compared with baseline. Compared with the control diet, the milk and the cheese diets attenuated the increase in LDL cholesterol. The magnitude of effect for milk tended to be smaller than for cheese but did not differ.	
Wennersberg et al. (2009)	The changes in LDL cholesterol were not significantly different between the milk and the control groups.	
HDL cholesterol (mmol/L)		
Abdullah et al. (2015)	Both diets reduced HDL cholesterol. No significant difference effect was observed between the diets.	HDL reduction similar to other SFA source Some dairy increase HDL, but vegetable oil rich in SFA increase more
Crichton et al. (2012)	A high dairy diet or a low dairy control diet made no significant changes in HDL cholesterol.	
Drouin-Chartier et al. (2015)	Consumption of the milk diet or NCEP diet significantly reduced plasma HDL levels with no difference between the diet's effects.	
Khaw et al. (2018)	Butter and coconut oil increased HDL, but coconut had a greater effect	
Kris-Etherton et al. (1993)	HDL cholesterol was unaffected by the experimental diets	
Park et al. (1996)	HDL cholesterol was higher when subjects ate diet 12:0 + 14:0 (palm kernel oil) compared with 14:0 + 16:0 (Butter and encapsulated myristic acid) and 16:0 + 18:0 (Lard, sheanut butter, and small amounts of coconut oil).	
Sørensen et al. (2014)	HDL cholesterol raised with dairy but the effect did not differ between the 3 diets (P . 0.1), although dairy had a smaller effect compared to control diet.	
Thorning et al. (2015)	Both interventions decreased HDL, but there were no differences between CHEESE and MEAT diets in HDL.	
Wennersberg et al. (2009)	HDL cholesterol levels were not significantly different between the milk and the control groups diets.	
Tryglicerides (mmol/L)		
Abdullah et al. (2015)	Both diets reduced TG equally.	Dairy intake may increase TG
Khaw et al. (2018)	No effect on TG with any of the interventions	
Crichton et al. (2012)	Both diets increased TG but there was no significant difference between the effects.	
Sørensen et al. (2014)	There tended to be an increase effect of the dairy diet on TG ($P = 0.08$), but pairwise comparisons did not reveal differences between diets.	
Thorning et al. (2015)	There were no significant differences between diets in TG.	
Wennersberg et al. (2009)	The changes in triglycerides were not significantly different between the milk and the control groups.	
Demmer et al. (2016)	After high-fat meal containing cheese consumption, postprandial TG concentration rose steadily ($P < 0{\cdot}05$ for all time points) with no sign of a decrease at the 6 h time point.	
Drouin-Chartier et al. (2015)	An important (−10.2%) reduction with NCEP diet and a small increase with milk diet was observed, although no statistical significance was found.	
Nguo et al. (2018)	SFA chain length has no acute differential effect on TG.	
Park et al. (1996)	Dietary treatment did not affect serum concentrations of TG.	

NCEP: National Cholesterol Education Program; HDL: high density lipoprotein cholesterol; LDL: low density lipoprotein cholesterol; TG: triglycerides.

Table 4. Main result for glycemic and blood pressure profile.

Author, year	Main result	Systematic review conclusions
Blood Pressure (mmHg)		
Abdullah et al. (2015)	Dairy intervention reduced systolic BP and increased diastolic BP and there was no statistically significant difference between the intervention and control.	Dairy can reduce blood pressure Effect probably associated to the increase in calcium
Crichton et al. (2012)	Dairy intervention increased systolic and diastolic BP and there was no statistically significant difference between the intervention and control.	
Drouin-Chartier et al. (2015)	Milk diet significantly reduced blood pressure compared with baseline values. The reduction in mean blood pressure with milk tended to be greater than after the NCEP diet (between-diet $P = 0.07$).	
Hilpert et al. (2009)	All three experimental diets significantly decreased blood pressure from screening. The addition of 3 servings of dairy to a diet high in fruits and vegetables had no effect on mean blood pressure changes, except in the subgroup characterized by appreciable decreases in intracellular calcium.	
Khaw et al. (2018)	Dairy intervention reduced systolic and diastolic BP with no significant changes among dairy and the other two fat interventions	
Thorning et al. (2015)	Blood pressure did not differ significantly between the 3 diets.	
Sørensen et al. (2014)	Blood pressure did not differ between the 3 diets ($P = 0.1$), although milk reduced more systolic and diastolic than cheese and control groups.	
Wennersberg et al. (2009)	Dairy intervention reduced systolic and diastolic BP but there was no significant difference between diets.	
Glycemia (mg/dL)		
Crichton et al. (2012)	There were no significant changes in fasting blood glucose in the high dairy and low dairy phases of the study.	No effect
Drouin-Chartier et al. (2015)	Both the milk diet and NCEP diets similarly reduced plasma fasting glucose levels compared with diet specific baseline values (between-diet $P = 0.22$).	
Khaw et al. (2018)	No effect with any of the interventions	
Smilowitz et al. (2011)	No changes were observed on plasma glucose in any of the 3 diets.	
Sørensen et al. (2014)	No effect of diets on fasting glucose concentrations were observed ($P = 0.10$).	
Wennersberg et al. (2009)	The changes in plasma glucose was not significantly different between the milk and the control groups.	
Demmer et al. (2016)	The glucose ($P = 0{\cdot}602$) response did not differ between the treatments.	
Thorning et al. (2015)	Dairy reduced glycemia but there was no difference compared to the meat diet. It was observed a tendency for a difference between diets in 3-h postprandial glucose.	

NCEP: National Cholesterol Education Program.

2015; Abdullah et al. 2015; Crichton et al. 2012; Demmer et al. 2016; Hilpert et al. 2009; Nguo et al. 2018; Wennersberg et al. 2009). Only two trials (Khaw et al. 2018; Abdullah et al. 2015) presented low risk of bias. Most trials presented concerns about the randomization process, especially due to lack of information on randomization sequence concealment and lack of comparison between baseline characteristics of the participants. Among crossover trials, the major concern was the lack of time to minimize any carry-over effect resulting in a rating of high risk of bias. Risk of bias assessment of included studies is summarized in Table S1.

Discussion

We conducted this systematic review of randomized controlled trials to examine the controversial role of dairy products on cardiometabolic diseases given the substantial burden of these diseases on public health. Our data showed that the intake of dairy appears to have a protective or similar effect on some cardiovascular risk factors relative to other SFA sources. The higher intake of dairy can decrease TC and increase HDL cholesterol. However, it can also increase LDL and TG, although these observed effects were small. It was also observed that the effect of dairy on several serum lipids varied according to the type dairy product used on intervention. In general, our hypothesis is partially supported: dairy products, although sources of SFA, apparently have a different effect on some cardiometabolic risk factors than other sources of SFA, and probably improve some metabolic parameters compared to other SFA of animal origin.

The beneficial effects of dairy may be associated with the diversity of SFA chain length and their metabolism, as well as other components present in dairy. Dairy products contain several fatty acids that are uncommon in other food sources (Wu and Palmquist 1991). For instance, odd-chain FA pentadecanoic acid (C15:0) and heptadecanoic acid (C17:0), as well as trans palmitoleic acid (trans C16:1) are exclusively produced in the rumen through microbial fermentation (Micha et al. 2010; Smedman et al. 1999; Liang et al. 2018). Although dairy contains a low amount of odd-chain FA, dairy intake increases circulating levels of C15:0, C17:0 and trans-16:1n-7 (Liang et al. 2018) and they are associated with lower risk of CVD (Astrup et al. 2019). Dairy fat can be found in diverse structures like: emulsion of fat globules enclosed in milk fat globule membrane (i.e.: milk), a water in oil emulsion (i.e.: butter), milk fat globules dispersed in a gelled milk protein matrix (i.e.: yogurt), and complex dairy matrices (i.e.: cheese) (Wolk et al. 1998). Therefore, the beneficial effects of dairy could be related to the way dairy fat is available in the food, changing its absorption and metabolism.

Dairy is a diverse food group from milk and plain yogurt to butter and ice cream. According to the NOVA food classification, sweetened dairy drinks are considered ultra-processed foods, cheese and yogurt are processed foods and milk is considered natural or minimally processed food (Monteiro et al. 2018). The degree of processing of dairy products should be considered when evaluating the benefits of dairy because ultra-processed products present high energy densities and low nutritional value, properties associated with health risk (Silva et al. 2018). In our study, dairy products evaluated were milk, yogurt, butter and cheese, therefore processed and minimally processed food. However, the loss of beneficial nutrients (e.g.butter), the increase energy density relative to nutrient density (e.g. butter, cream, cheese) and the addiction of sugars (e.g. sweetened milk, ice cream, frozen yogurt, sweetened yogurts) during processing should be the main concerns when evaluating the effects of dairy on cardiometabolic health. Also, although classified as processed food, yogurts and cheese might present potential benefits from fermentation (Trichia et al. 2020). Thus, a dietary pattern composed of more dairy products, especially those minimally processed, increases the availability of calcium, magnesium and potassium (Huth et al. 2008) and may help improve cardiometabolic parameters such as blood pressure. In our study, dairy intake was associated with a reduction on blood pressure similar to the control diets. however; the dairy effect seems to be greater than other SFA sources, probably due to its mineral content.

Excess adiposity, especially in the abdominal region, is known to favor the development of cardiometabolic risk such as insulin resistance, hypertriglyceridemia and hypertension (Britton and Fox 2011; Despres et al. 2008; Mathieu, Lemieux, and Despres 2010; Ribeiro Filho et al. 2006; Stefan et al. 2008). From our systematic review, the intake of dairy seems to play a protective role on waist circumference and a controversial role on body fat percentage. Dairy intake tends to reduce waist circumference of participants with BMI less than 30 Kg/m^2. Mirmiran and collaborators found that subjects who consumed a high number of dairy products per day, usually had BMI less than 25 Kg/m^2 (Mirmiran, Esmaillzadeh, and Azizi 2005). A meta-analysis of dairy intake and metabolic syndrome risk in cohort studies, found a protective role related to an increment of 1 serving/day of dairy (RR 0.88; 95% CI 0.82–0.95; I^2=55.6%) (Kim and Je 2016).

A meta-analysis of 29 RCTs on the effects of increased dairy intake on body weight and fat, found no improvements in weight with dairy intervention, but it favored a significant reduction of body fat, especially when combined with a calorie restricted diet (Chen et al. 2012). Concerning body fat percentage, only one study demonstrated a reduction of body fat percentage with dairy intake and in this trial the proportion of SFA in the diet was around 10% of total energy intake (Smilowitz et al. 2011). Previous studies evidenced a positive association between long-chain SFA and BMI (Chen et al. 2012), while no association was found for medium-chain SFA, such as lauric acid (C 12:0) present in milk (Raatz et al. 2017). The discussed findings support the hypotheses that a maximum consumption of SFA up to 10% of total energy intake is beneficial to health or has no adverse effects in a diet with more dairy products compared to a diet with none or less dairy. However, one can easily exceed this value if high fat dairy products like butter and sour cream, composed of almost 90% SFA are consumed without caution.

Our findings indicate that dairy SFA sources affects TC and LDL-c, being directly linked with the type of fat used as intervention and control. Butter tends to raise TC (Smilowitz et al. 2011; Khaw et al. 2018; Kris-Etherton et al. 1993) and LDL-c (Khaw et al. 2018; Park et al. 1996), but in general dairy products reduced these cholesterol fractions when compared with other SFA of animal origin like red meat (Park et al. 1996; Drouin-Chartier et al. 2015; Sørensen et al. 2014; Thorning et al. 2015). Similar effects were observed in a meta-analysis of RCT: the effect of cheese intake on blood lipids depends on the source of SFA used as comparator (de Goede et al. 2015). Cheese intake increased TC and LDL-c (de Goede et al. 2015) compared to tofu or fat-modified cheese, which has a more favorable P/S ratio. When compared with butter of a similar P/S ratio, hard cheese lowered TC by 5% and LDL-C by 6.5% (de Goede et al. 2015). We can conclude that possibly, different types of dairy products could promote different lipid profiles. In an acute study, a high-fat meal with sour cream induced a significantly higher TG increase within a 6 h period compared to all other dairy products. Moreover, a significantly higher HDL increase was observed compared to the intake of cheese (Hansson et al. 2019). Also, palmitic (C16:0) acid is associated with a greater increase in TC and LDL-c compared to lauric acid present in most vegetable fats and milk (Denke and Grundy 1992). A meta-analysis of 60 RCT showed that the cholesterol-raising effect of lauric acid is proportionally higher for HDL than LDL, promoting a better LDL:HDL ratio (Mensink et al. 2003).

The effect of the different dairy on HDL was tested in an RCT which compared butter and cheese intake. The diet with butter significantly increased HDL-mediated cholesterol efflux capacity compared with cheese (Brassard et al. 2018). Likewise, among institutionalized seniors, higher intake of fat or SFA from dairy products or 'meat' was associated with higher HDL levels. However, only total dairy fat, SFA and number of servings were associated with a lower TC:HDL ratio (Liu et al. 2019).

Our systematic review observed a tendency to increase TG with a high dairy intervention, whereas no difference in fasting TG was found by a meta-analysis of RCT comparing $\geq$ 3 dairy servings/day with $\leq$ 1 dairy serving/day (Drouin-Chartier et al. 2016). Several trials have compared whole-fat milk with skimmed milk (Engel, Elhauge, and Tholstrup 2018; Hidaka et al. 2012; Steinmetz et al. 1994) and neither types of milk changed serum TG. One reasonable explanation for our findings could be the metabolism involved in long chain and medium chain TG absorption. Long chain fatty acids travel through the lymphatic system via chylomicrons after being absorbed in the large intestine; on the other hand, medium chain fatty acids diffuse through the intestinal wall to the portal system, enabling direct access to the liver, a faster process that could increase serum TG (Lemarie et al. 2015).

Potential limitations of this study should be considered, such as the nutritional status of the participants, the presence of underlying diseases, level of physical activity as well as the follow-up period of each intervention and control which constitute a source of heterogeneity in the studied population. Caution is required when generalizing results to other populations, since most studies used small samples, specific subgroups, and investigated a single sex. On the other hand, no date limit was defined for the search; therefore, a large number of articles were found, making it possible to compare several cardiometabolic risks factors. Although a wide search was performed, a small number of articles were found for each outcome. Also, intervention periods shorter than 12 weeks, uncontrolled macronutrient distribution of diets between studies, may introduce confusion bias and alter results.

In spite of the limitations, this study has several strengths, such as the use of a rigorous methodology based on PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses); a comprehensive literature search, including six electronic databases (Scopus, PubMed, Embase, Web of Science, Central Cochrane and Scielo); the search, selection and data extraction of the studies were performed independently and in duplicate by two researchers, with third-party resolution of discordance; a well-defined eligibility criteria which prioritize only studies focused on the source of SFA, minimizing any differences resulting from other nutrients.

Conclusion

In view of the findings of this systematic review, the impact of dairy products on cardiometabolic risk in adults is not totally clear. Intake of dairy appears to have a protective effect on waist circumference, TC, HDL and blood pressure outcomes compared to other sources of SFA. We also conclude that the effect of dairy intake on blood lipids depends on the source of SFA used as comparator. Larger samples, longer interventions and better methodological quality of clinical trials are needed to elucidate the role of dairy in diet and its impact on clinical outcomes associated with cardiovascular health.

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References

Abdullah, M. M. H., A. Cyr, M.-C. Lépine, M.-È. Labonté, P. Couture, P. J. H. Jones, and B. Lamarche. 2015. Recommended dairy product intake modulates circulating fatty acid profile in healthy adults: A multi-centre cross-over study. *British Journal of Nutrition* 113 (3): 435–44. doi: 10.1017/S0007114514003894.

Astrup A., H. C. S. Bertram, J.-P. Bonjour, L. C. P. de Groot, M. C. de Oliveira Otto, E. L. Feeney, M. L. Garg, I. Givens, F. J. Kok, R. M. Krauss, et al. 2019. WHO draft guidelines on dietary saturated and trans fatty acids: time for a new approach? *BMJ (Clinical Research ed.)* 366:l4137. doi: 10.1136/bmj.l4137.

Brassard, D., B. J. Arsenault, M. Boyer, D. Bernic, M. Tessier-Grenier, D. Talbot, A. Tremblay, E. Levy, B. Asztalos, P. J. Jones, et al. 2018. Saturated fats from butter but not from cheese increase HDL-mediated cholesterol efflux capacity from J774 macrophages in men and women with abdominal obesity. *The Journal of Nutrition* 148 (4):573–80. doi: 10.1093/jn/nxy014.

Britton, K. A., and C. S. Fox. 2011. Ectopic fat depots and cardiovascular disease. *Circulation* 124 (24):837–41. doi: 10.1161/CIRCULATIONAHA.111.077602.

Chen, M., A. Pan, V. S. Malik, and F. B. Hu. 2012. Effects of dairy intake on body weight and fat: A meta-analysis of randomized controlled trials. *The American Journal of Clinical Nutrition* 96 (4): 735–47. doi: 10.3945/ajcn.112.037119.

Crichton, G. E., P. R. C. Howe, J. D. Buckley, A. M. Coates, and K. J. Murphy. 2012. Dairy consumption and cardiometabolic health: Outcomes of a 12-month crossover trial. *Nutrition and Metabolism* 9:1–11.

de Goede, J., J. M. Geleijnse, E. L. Ding, and S. S. Soedamah-Muthu. 2015. Effect of cheese consumption on blood lipids: A systematic review and meta-analysis of randomized controlled trials. *Nutrition Reviews* 73 (5):259–75. doi: 10.1093/nutrit/nuu060.

Dehghan, M., A., Mente, S. Rangarajan, P. Sheridan, V. Mohan, R. Iqbal, R. Gupta, S. Lear, E. Wentzel-Viljoen, A. Avezum, et al. 2017. Articles Associations of fats and carbohydrate intake with cardiovascular disease and mortality in 18 countries from five continents (PURE): A prospective cohort study. *The Lancet.* 6736 (17):1–13. 10.1016/S0140-6736(17)32252-3.

DeLany, J. P., M. M. Windhauser, C. M. Champagne, and G. A. Bray. 2000. Differential oxidation of individual dietary fatty acids in humans. *The American Journal of Clinical Nutrition* 72 (4):905–11. doi: 10.1093/ajcn/72.4.905.

Demmer, E., M. D. Van Loan, N. Rivera, T. S. Rogers, E. R. Gertz, J. B. German, A. M. Zivkovic, and J. T. Smilowitz. 2016. Consumption of a high-fat meal containing cheese compared with a vegan alternative lowers postprandial C-reactive protein in overweight and obese individuals with metabolic abnormalities: A randomised controlled cross-over study. *Journal of Nutritional Science* 5:1–12. doi: 10.1017/jns.2015.40.

Denke, M. A., and S. M. Grundy. 1992. Comparison of effects of lauric acid and palmitic acid on plasma lipids and lipoproteins. *The American Journal of Clinical Nutrition* 56 (5):895–8. doi: 10.1093/ajcn/56.5.895.

Despres, J. P., B. J. Arsenault, M. Côté, A. Cartier, and I. Lemieux. 2008. Abdominal obesity: The cholesterol of the 21st century? *Canadian* Journal of Cardiology 24:7D–12D. doi: 10.1016/S0828-282X(08)71043-2.

Drehmer, M., M. A. Pereira, M. Ine, S. Alvim, P. A. Lotufo, V. C. Luft, and B. B. Duncan. 2016. Total and full-fat, but not low-fat, dairy product intakes are inversely associated with metabolic syndrome in adults 1, 2. *The Journal of Nutrition* 146 (1):81–9. doi: 10.3945/jn.115.220699.

Drouin-Chartier, J.-P., J. A. Côté, M.-È. Labonté, D. Brassard, M. Tessier-Grenier, S. Desroches, P. Couture, and B. Lamarche. 2016. Comprehensive review of the impact of dairy foods and dairy fat on cardiometabolic risk. *Advances in Nutrition: An International Review Journal* 7 (6):1041–51. doi: 10.3945/an.115.011619.

Drouin-Chartier, J.-P., J. Gagnon, M.-È. Labonté, S. Desroches, A. Charest, G. Grenier, S. Dodin, S. Lemieux, P. Couture, B. Lamarche, et al. 2015. Impact of milk consumption on cardiometabolic risk in postmenopausal women with abdominal obesity. *Nutrition Journal* 14 (1):6–15. doi: 10.1186/1475-2891-14-12.

Duarte, C. K., A. L. T. Santos, C. Kirst, G. S. Nunes, K. Franceschi, M. J. Azevedo, T. Zelmanovitz. 2018. Dietary source of saturated fat and percentage body fat of patients with type 2 diabetes mellitus: A cross-sectional study. *Food Science & Nutrition* 7:195–204. doi: 10.1002/fsn3.853.

Engel, S., M. Elhauge, and T. Tholstrup. 2018. Effect of whole milk compared with skimmed milk on fasting blood lipids in healthy adults: A 3-week randomized crossover study. *European Journal of Clinical Nutrition* 72 (2):249–54. doi: 10.1038/s41430-017-0042-5.

Fleming, J. A., and P. M. Kris-Etherton. 2016. Macronutrient content of the diet: what do we know about energy balance and weight maintenance? *Current Obesity Reports* 5 (2):208–13. doi: 10.1007/s13679-016-0209-8.

Garaulet, M., J. J. Hernandez-Morante, F. J. Tebar, and S. Zamora. 2011. Relation between degree of obesity and site-specific adipose tissue fatty acid composition in a Mediterranean population. *Nutrition* 27 (2):170–6. doi: 10.1016/j.nut.2010.01.004.

Global Health Estimates 2016. 2018. *Disease burden by cause, age, sex, by country and by region, 2000-2016*. Geneva: World Health Organization.

Hansson, P., K. B. Holven, L. K. L. Øyri, H. K. Brekke, A. S. Biong, G. O. Gjevestad, G. S. Raza, K.-H. Herzig, M. Thoresen, S. M. Ulven, et al. 2019. Meals with similar fat content from different dairy products induce different postprandial triglyceride responses in healthy adults: A randomized controlled cross-over trial. *The Journal of Nutrition* 149 (3):422–31. doi: 10.1093/jn/nxy291.

Hidaka, H., M. Takiwaki, M. Yamashita, K. Kawasaki, M. Sugano, and T. Honda. 2012. Consumption of nonfat milk results in a less atherogenic lipoprotein profile: a pilot study. *Annals* of Nutrition and Metabolism 61 (2):111–6. doi: 10.1159/000339261.

Higgins, J. P. T., and S. Green. Cochrane Handbook for Systematic Reviews of Interventions, version 5.1.0. The Cochrane Collaboration. 2011. Accessed February 25, 2019. http://handbook.cochrane.org.

Higgins, J. P. T., J. A. C. Sterne, J. Savović, M. J. Page, A. Hróbjartsson, I. Boutron, B. Reeves, and S. Eldridge. 2016. A revised tool for assessing risk of bias in randomized trials. In: *Cochrane Database of Systematic Reviews*, vol. 10, 29–31.

Hilpert, K. F., S. G. West, D. M. Bagshaw, V. Fishell, L. Barnhart, M. Lefevre, M. M. Most, M. B. Zemel, M. Chow, A. L. Hinderliter, et al. 2009. Effects of dairy products on intracellular calcium and blood pressure in adults with essential hypertension. *Journal of the American College of Nutrition* 28 (2):142–9. doi: 10.1080/07315724.2009.10719765.

Hooper, L., A. Abdelhamid, D. Bunn, T. Brown, C. D. Summerbell, and C. Skeaff. 2015. Effects of total fat intake on body weight. *Cochrane Database Systematic Review* 7 (8):CD011834.

Huth, P. J., V. L. Fulgoni III, D. B. DiRienzo, and G. D. Miller. 2008. Role of dairy foods in the Dietary Guidelines. *Nutrition* Today 43 (6):226–34. doi: 10.1097/01.NT.0000342703.57916.46.

Jacome-Sosa, M., E. J. Parks, R. S. Bruno, E. Tasali, G. F. Lewis, B. O. Schneeman, and T. M. Rains. 2016. Postprandial metabolism of macronutrients and cardiometabolic risk: recent developments, emerging concepts, and future directions. *Advances in Nutrition* 7 (2):364–74. doi: 10.3945/an.115.010397.

Khaw, K.-T., S. J. Sharp, L. Finikarides, I. Afzal, M. Lentjes, R. Luben, and N. G. Forouhi. 2018. Randomised trial of coconut oil, olive oil or butter on blood lipids and other cardiovascular risk factors in healthy men and women. *BMJ Open* 8 (3):e020167–14. doi: 10.1136/bmjopen-2017-020167.

Kim, Y., and Y. Je. 2016. Dairy consumption and risk of metabolic syndrome: A meta-analysis. *Diabetic* Medicine 33 (4):428–40. doi: 10.1111/dme.12970.

Kishino, T., K. Watanabe, T. Urata, M. Takano, T. Uemura, K. Nishikawa, Y. Mine, M. Matsumoto, K. Ohtsuka, H. Ohnishi, et al. 2008. Visceral fat thickness in overweight men correlates with alterations in serum fatty acid composition. *Clinica Chimica Acta* 398 (1–2):57–62. doi: 10.1016/j.cca.2008.08.010.

Kris-Etherton, P. M., J. Derr, D. C. Mitchell, V. A. Mustad, M. E. Russell, E. T. McDonnell, D. Salabsky, and T. A. Pearson. 1993. The role of fatty acid saturation on plasma lipids, lipoproteins, and apolipoproteins: I. Effects of whole food diets high in cocoa butter, olive oil, soybean oil, dairy butter, and milk chocolate on the plasma lipids of young men. *Metabolism* 42 (1):121–9. doi: 10.1016/0026-0495(93)90182-N.

Lemarie, F., E. Beauchamp, P. Legrand, and V. Rioux. 2015. Revisiting the metabolism and physiological functions of caprylic acid (C8:0) with special focus on ghrelin octanoylation. *Biochimie* 120:40–8. doi: 10.1016/j.biochi.2015.08.002.

Liang, J., Q. Zhou, W. Kwame Amakye, Y. Su, and Z. Zhang. 2018. Biomarkers of dairy fat intake and risk of cardiovascular disease: A systematic review and meta analysis of prospective studies. *Critical* Reviews in Food Science and Nutrition 58 (7):1122–30. Epub 2017 Jul 5. doi: 10.1080/10408398.2016.1242114.

Liu, Y., S. Poon, E. Seeman, D. L. Hare, M. Bui, and S. Iuliano. 2019. Fat from dairy foods and 'meat' consumed within recommended levels is associated with favourable serum cholesterol levels in institutionalised older adults. *Journal* of Nutritional Science 8:1–8. doi: 10.1017/jns.2019.5.

Mathieu, P., I. Lemieux, and J. P. Despres. 2010. Obesity, inflammation, and cardiovascular risk. *Clinical* Pharmacology *&* Therapeutics 87:407–16. doi: 10.1038/clpt.2009.311.

Mensink, R. P., P. L. Zock, A. D. Kester, and M. B. Katan. 2003. Effects of dietary fatty acids and carbohydrates on the ratio of serum total to HDL cholesterol and on serum lipids and apolipoproteins: A meta-analysis of 60 controlled trials. *The American Journal of Clinical Nutrition* 77 (5):1146–55. doi: 10.1093/ajcn/77.5.1146.

Micha, R., I. B. King, R. N. Lemaitre, E. B. Rimm, F. Sacks, X. Song, D. S. Siscovick, and D. Mozaffarian. 2010. Food sources of individual plasma phospholipid trans fatty acid isomers: The cardiovascular health study. *The American Journal of Clinical Nutrition* 91 (4):883–93. doi: 10.3945/ajcn.2009.28877.

Mirmiran, P., A. Esmaillzadeh, and F. Azizi. 2005. Dairy consumption and body mass index: An inverse relationship. *International Journal of Obesity* 29 (1):115–21. doi: 10.1038/sj.ijo.0802838.

Moher, D., A. Liberati, J. Tetzlaff, and D. G. Altman, The PRISMA Group. 2009. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine* 6 (7): e1000097. doi: 10.1371/journal.pmed.1000097.

Monteiro, C. A., G. Cannon, J. C. Moubarac, R. B. Levy, M. L. C. Louzada, and P. C. Jaime. 2018. The UN Decade of Nutrition, the NOVA food classification and the trouble with ultra-processing. *Public Health Nutrition* 21 (1):5–17. doi: 10.1017/S1368980017000234.

Nguo, K., C. E. Huggins, H. Truby, A. J. Sinclair, R. E. Clarke, and M. P. Bonham. 2018. No effect of saturated fatty acid chain length on meal-induced thermogenesis in overweight men. *Nutrition Research* 51:102–10. doi: 10.1016/j.nutres.2018.01.003.

Panth, N., K. A. Abbott, C. B. Dias, K. Wynne, and M. L. Garg. 2018. Differential effects of medium- and long-chain saturated fatty acids on blood lipid profile: A systematic review and meta-analysis. *American* Journal of Clinical Nutrition 108:1–12.

Park, S., J. T. Snook, L. Bricker, M. Morroco, R. Van Voorhis, E. Stasny, S. Park, and M.-S. Lee. 1996. Relative effects of high saturated fatty acid levels in meat, dairy products, and tropical oils on serum lipoproteins and low-density lipoprotein degradation by mononuclear cells in healthy males. *Metabolism* 45 (5):550–8. doi: 10.1016/S0026-0495(96)90023-2.

Raatz, S. K., Z. Conrad, L. K. Johnson, M. J. Picklo, and L. Jahns. 2017. Relationship of the reported intakes of fat and fatty acids to body weight in US adults. *Nutrients* 9 (5):438. doi: 10.3390/nu9050438.

Ramsden, C. E., D. Zamora, S. Majchrzak-Hong, K. R. Faurot, S. K. Broste, R. P. Frantz, and J. R. Hibbeln. 2016. Re-evaluation of the traditional diet-heart hypothesis: Analysis of recovered data from Minnesota Coronary Experiment (1968-73). *BMJ* 353:i1246. 10.1136/bmj.i1246.

Ribeiro Filho, F. F., L. S. Mariosa, S. R. G. Ferreira, and M. T. Zanella. 2006. Gordura visceral e síndrome metabólica: Mais que uma simples associação. *Arquivos* Brasileiros *de* Endocrinologia *&* Metabologia 50 (2):230–8. doi: 10.1590/S0004-27302006000200009.

Silva, F. M., L. Giatti, R. C. de Figueiredo, M. C. B. Molina, L. O. de Cardoso, B. B. Duncan, and S. M. Barreto. 2018. Consumption of ultra-processed food and obesity: Cross sectional results from the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil) cohort (2008–2010). *Public Health Nutrition* 21 (12):2271–9. doi: 10.1017/S1368980018000861.

Smedman, A. E., I. B. Gustafsson, L. G. Berglund, and B. O. Vessby. 1999. Pentadecanoic acid in serum as a marker for intake of milk fat: Relations between intake of milk fat and metabolic risk factors. *The American Journal of Clinical Nutrition* 69 (1):22–9. doi: 10.1093/ajcn/69.1.22.

Smilowitz, J. T., M. M. Wiest, D. Teegarden, M. B. Zemel, J. B. German, and M. D. Van Loan. 2011. Dietary fat and not calcium supplementation or dairy product consumption is associated with changes in anthropometrics during a randomized, placebo-controlled energy-restriction trial. *Nutrition & Metabolism* 8 (1):10. doi: 10.1186/1743-7075-8-67.

Sørensen, K. V., T. K. Thorning, A. Astrup, M. Kristensen, and J. K. Lorenzen. 2014. Effect of dairy calcium from cheese and milk on fecal fat excretion, blood lipids, and appetite in young men. *The* American Journal of Clinical Nutrition 99:984–91. doi: 10.3945/ajcn.113.077735.

Stefan, N., K. Kantartzis, J. Machann, F. Schick, C. Thame, K. Rittig, et al. 2008. Identification and characterization of metabolically benign obesity in humans. *Archives of Internal Medicine* 168 (15):1609–16. doi: 10.1001/archinte.168.15.1609.

Steinmetz, K. A., M. T. Childs, C. Stimson, L. H. Kushi, P. G. McGovern, J. D. Potter, and W. K. Yamanaka. 1994. Effect of consumption of whole milk and skim milk on blood lipid profiles in healthy men. *The American Journal of Clinical Nutrition* 59 (3):612–8. doi: 10.1093/ajcn/59.3.612.

Thorning, T. K., F. Raziani, N. T. Bendsen, A. Astrup, T. Tholstrup, and A. Raben. 2015. Diets with high-fat cheese, high-fat meat, or carbohydrate on cardiovascular risk markers in overweight postmenopausal women: A randomized crossover trial. *The American Journal of Clinical Nutrition* 102 (3):573–81. doi: 10.3945/ajcn.115.109116.

Trichia, E., R. Luben, K.-T. Khaw, N. J. Wareham, F. Imamura, and N. G. Forouhi. 2020. The associations of longitudinal changes in consumption of total and types of dairy products and markers of metabolic risk and adiposity: Findings from the European Investigation into Cancer and Nutrition (EPIC)–Norfolk study, United Kingdom. *The American Journal of Clinical Nutrition* (s.l): 1–9.. doi: 10.1093/ajcn/nqz335.

Wang, H., L. M. Troy, G. T. Rogers, C. S. Fox, N. M. McKeown, J. B. Meigs, and P. F. Jacques. 2014. Longitudinal association between dairy consumption and changes of body weight and waist circumference: The Framingham Heart Study. *International Journal of Obesity* 38 (2):299–305. doi: 10.1038/ijo.2013.78.

Wennersberg, M. H., A. Smedman, A. M. Turpeinen, K. Retterstøl, S. Tengblad, E. Lipre, A. Aro, P. Mutanen, I. Seljeflot, S. Basu, et al. 2009. Dairy products and metabolic effects in overweight men and women: Results from a 6-mo intervention study. *The American Journal of Clinical Nutrition* 90 (4):960–8. doi: 10.3945/ajcn.2009.27664.

Wolk, A., B. Vessby, H. Ljung, and P. Barrefors. 1998. Evaluation of a biological marker of dairy fat intake. *The American Journal of Clinical Nutrition* 68 (2):291–5. doi: 10.1093/ajcn/68.2.291.

World Health Organization. 2017. Cardiovascular diseases (CVDs). Accessed February 25, 2019. https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds).

Wu, Z., and D. L. Palmquist. 1991. Synthesis and biohydrogenation of fatty acids by ruminal microorganisms in vitro. *Journal* of Dairy Research 74:3035–46. doi: 10.3168/jds.S0022-0302(91)78489-0.

Yu, Y., Z. Cai, J. Zheng, J. Chen, X. Zhang, X.-F. Huang, and D. Li. 2012. Serum levels of polyunsaturated fatty acids are low in Chinese men with metabolic syndrome, whereas serum levels of saturated fatty acids, zinc, and magnesium are high. *Nutrition Research* 32 (2):71–7. doi: 10.1016/j.nutres.2011.12.004.