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REVIEW ARTICLE

Considering the Impact of Elevated Saturated Fat Intake in the Context of Full Fat Dairy Products and Red Meats on Cardiovascular Health, A Systematic Review

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Abstract

Background: Within the medical field there is considerable controversy over the impact of saturated fatty acid (SFA) content in diet and its relationship to cardiovascular disease in the general healthy population. The most common sources of elevated SFA content in the USA's diet are milk and milk products, such as cheese, yogurt, and butter, as well as red meats, including beef and pork. These foods are reported to have relatively high levels of saturated fatty acids; however, they also contain multiple other nutrients which are highly beneficial to health and are more bioavailable than the same nutrients from plant-based foods.
Objective: To test the hypothesis that intakes of SFA content in the context of minimally processed whole food sources, such as full-fat dairy and red meat products, negatively impact cardiovascular health. Cardiovascular health will be measured using the validated cardiovascular disease risk factors of blood lipoproteins and lipid classes, including low density lipoprotein cholesterol (LDL-C), high density lipoprotein cholesterol (HDL-C), triglycerides (TG), and total cholesterol (TC).
Methods: A bibliographic search was performed in the databases of PubMed, CINAHL Complete, Cochrane Library, and Agricola. Data was extracted using an adapted data collection form derived from PRISMA and The Cochrane Collaboration guidelines. Study quality and risk of bias were analyzed using the Academy of Nutrition and Dietetics Quality Criteria Checklist.
Results and Conclusion: There is some evidence which supports minimally processed lean red meat does not have a negative impact on cardiovascular health apart from overall elevated SFA content.
Minimally processed, full-fat dairy products, including cheese and yogurt, have not been demonstrated to cause negative impacts on blood cholesterol levels when consumed in the context of an overall healthy diet pattern, including DASH and Mediterranean diet patterns. A notable exception to this is the effect of butter on LDL-C and TC.

Key words: red meat, dairy products, saturated fatty acids, blood cholesterol, cardiovascular health 3

1 | INTRODUCTION

The global and local economic, physical, and psychological impact of cardiovascular diseases (CVDs) is undeniably remarkable in health care around the world (1,2). For some perspective on numerical impacts of CVDs around the world and in the United States of America, in 2019 the World Health Organization (WHO) estimated over 30% of death worldwide resulted from conditions or complications associated with CVDs (1). In 2021, the Center for Disease Control and Prevention, the United States of America's (USA) leading health research and information agency, stated 20% of deaths in the USA are related to CVDs (2). That is approximately 700,000 deaths in one year in the USA, not including the impact to daily life of those who are still living with a CVDs (2,3). The estimated cost of health care specific for CVDs in the USA was over $238 billion in 2021 (2). Because conditions

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related to the cardiovascular system of the human body are an enormous toll on world health, growth in understanding and treatment for CVDs and comorbidities are being sought as a number one priority of healthcare agencies across the globe.

In research for how to treat CVDs, several key points have come into focus. The points are staples preached to USA citizens with regularity yet understandings on how and where to apply them for everyone served are under acute debate. The key points include the importance of a healthful diet, physical activity with consistency, moderation in tobacco use, and alcohol consumption (1,2,4).

Within the medical field, and particularly the field of nutrition and dietetics, there is considerable controversy over the impact of saturated fatty acid (SFA) content in diet and the relationship of these compounds to CVDs prevalence and risk in the general population (5-9). The most common sources of elevated SFA content in the USA's diet are milk and milk products, such as yogurt and butter, as well as red meats, including beef, pork, and lamb (10). These foods are reported to have relatively high levels of SFAs, however, they also contain multiple other nutrients which are highly beneficial to health such as protein, probiotics, fat soluble vitamins A, D, E, K, calcium, magnesium, phosphorus, multiple B vitamins, including riboflavin, folate, and thiamin (11-13). In addition to the rich presence of the beneficial nutrients, it is becoming increasingly evident many animal sources of the nutrients listed above are more bioavailable than plant sources of the same nutrients, and thus are more efficient at meeting nutrition needs (5,11,13,14). The conflicting information regarding food and its role in aiding or frustrating cardiovascular health contributes to much public confusion and controversy.

This controversy brings into question the Dietary Guidelines for Americans 2020-2025 in the USA which recommend intake of SFAs be restricted to 10% or less of total daily energy intake for the general population, regardless of food source of SFA content (15). Currently, USA national recommendations advise all foods with elevated SFAs should be consumed sparingly or communicate there is a consistent need to alter foods and eating patterns to decrease SFA content, such as the message that all populations of USA adults, as well as most children, should drink reduced fat milk and consume reduced fat cheeses (15). Because of how many industries the guidelines impact, besides USA healthcare, it is essential for healthcare professionals from all disciplines to constantly evaluate if current procedures and guidelines are the most accurate depiction available or if refinement is needed.

The objective of this systematic review is to highlight and further understand the importance and intricacies of a healthful diet and its relationship to CVD and test the hypothesis that intakes of SFA content in the context of minimally processed whole food sources, such as full fat dairy and red meat products, negatively impact cardiovascular health. For this systematic review, measurement of cardiovascular health will be described by the validated CVD risk factors of blood lipoproteins and lipid classes, including low density lipoprotein cholesterol (LDL-C), high density lipoprotein cholesterol (HDL-C), triglycerides (TG), and total cholesterol (TC), which are currently defined standard measures of cardiovascular health and cardiovascular health risk (16,17)

2 | METHODS

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) organizational guidelines (18).

Protocol and Registration

This systematic review was registered with the International Prospective Register of Systematic Reviews (PROSPERO) before data collection began in June 2024. (registration ID: CRD42024566135).

Search Strategy

A bibliographic search was performed in the databases of PubMed, CINAHL Complete, Cochrane Library, and Agricola. Initial filters such as publication date, type, and language were used in combination with key terms and the Boolean operators "AND" and "OR" to obtain results and are depicted in various tables below (see Table 1, 2, Figure 1). The systematic search results and filtering are shown in Figure 2 in the results section and depict the numbers obtained for each part of the research process.

Table 1. Key Words and MeSH Terms for Search

			Search Strategy Using Combined Terms
Adult, Male, Female, Humans	Butter, Cheese, Yogurt, Dairy Products, Red meat, Diet, Dietary Fats, Dietary Fats / administration & dosage, dietary fats / saturated	Cardiovascular diseases / blood; cholesterol / blood; fatty Acids/ pharmacology; Cholesterol, HDL / blood; Cholesterol, LDL / blood; lipoproteins / blood	(Milk OR Butter OR Cheese OR Yoghurt OR Yogurt OR Dairy products OR Red meat) AND (Dietary fats OR Dietary fat OR Saturated fat OR Saturated fats) AND (Fatty acids OR Cholesterol OR HDL OR LDL OR Lipoproteins OR Triglycerides OR Lipids)

Table 2. Full Search Strategy

Database		Filters Used
PubMed	(Milk OR Butter OR Cheese OR Yoghurt OR Yogurt OR Dairy products OR Red meat) AND (Dietary fats OR Dietary fat OR Saturated fat OR Saturated fats) AND (Fatty acids OR Cholesterol OR HDL OR LDL OR Lipoproteins OR Triglycerides OR Lipids)	Full text, clinical trial, humans, English, from 2014/1/1 – current.
CINAHL Complete	(Milk OR Butter OR Cheese OR Yoghurt OR Yogurt OR Dairy products OR Red meat) AND (Dietary fats OR Dietary fat OR Saturated fat OR Saturated fats) AND (Fatty acids OR Cholesterol OR HDL OR LDL OR Lipoproteins OR Triglycerides OR Lipids)	Apply equivalent subjects, Publication Date: 2014/01/01-current, linked full text, English Language, Peer Reviewed, Human, Age Groups: All Adult
Cochrane Library	(Milk OR Butter OR Cheese OR Yoghurt OR Yogurt OR Dairy products OR Red meat) AND (Dietary fats OR Dietary fat OR Saturated fat OR Saturated fats) AND (Fatty acids OR Cholesterol OR HDL OR LDL OR Lipoproteins OR Triglycerides OR Lipids)	Published between Jan 2014-current, in Trials
Agricola	(Milk OR Butter OR Cheese OR Yoghurt OR Yogurt OR Dairy products OR Red meat) AND (Dietary fats OR Dietary fat OR Saturated fat OR Saturated fats) AND (Fatty acids OR Cholesterol OR HDL OR LDL OR Lipoproteins OR Triglycerides OR Lipids)	Apply equivalent subjects, published 2014-current, linked full text, English language.

Eligibility Criteria

Full eligibility criteria are detailed in Table 3. A brief description of this criteria include: Participants must be generally healthy adults who do not have diagnosis of CVD or related conditions at baseline, standardized measurements of blood lipids levels must be clearly presented at baseline and the end of study; participants must not have had a cardiovascular event within the last 5 years of the study, and intervention foods must be from unaltered and minimally processed full fat dairy products and red meats.

Data Extraction and Quality Assessment

Data from selected articles were extracted by the primary author using an adapted data collection form derived from PRISMA organizational guidelines and guidelines from The Cochrane Collaboration (18,19). Study articles were assessed for risk of bias, study design and execution quality, and reporting of findings. Study quality and risk of bias were analyzed using the Academy of Nutrition and Dietetics Quality Criteria Checklist (20). According to this grading system, there are three possible scores, positive (+), neutral (∅) and negative (-). A positive (+) rating indicates the article has appropriately addressed issues of inclusion and exclusion, bias, generalizability, data collection and analysis. A negative (-) rating indicates a report has not distinctly addressed these issues, while a neutral (∅) rating indicates the article is neither exceptionally strong nor exceptionally weak in addressing these issues.

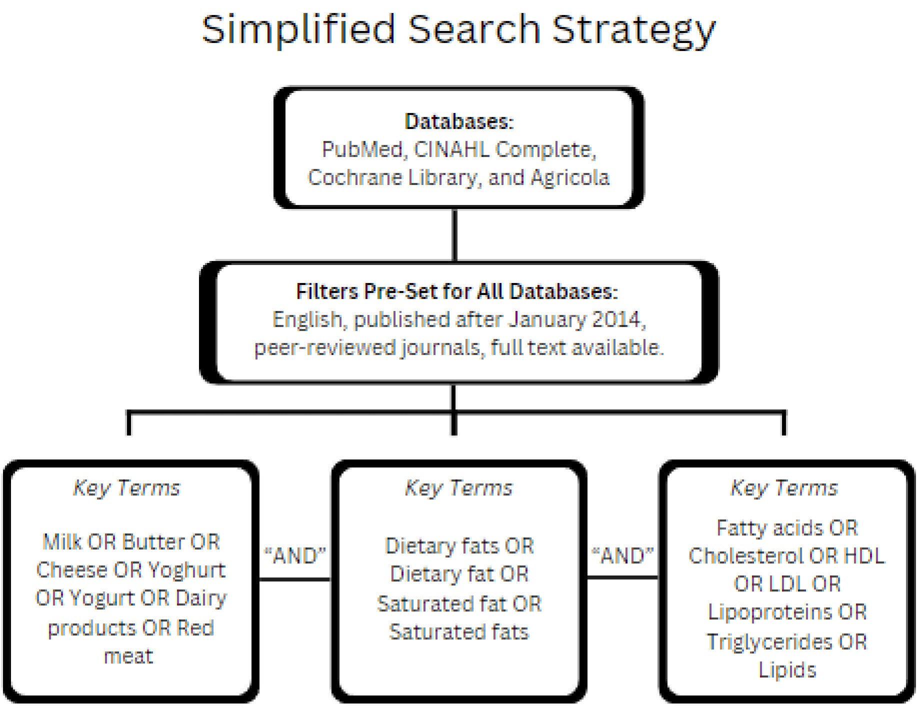

Fig. 1: Simplified Search Strategy

Table 3. Eligibility Criteria

Criteria	**Inclusion**	**Exclusion**
Age	18+ years	Children (18 years and under)
Gender	Male & Female	N/A
Setting / Country	Countries which use standardized measures of blood lipid levels, particularly including developed countries, such as USA, EU, and Australia.	Countries which do not provide standardized measures of blood lipid levels in their reports. None otherwise restricted.
Health Status / Problem / Condition	No diagnosed CVD or related conditions, such as diabetes at baseline.	Diagnosis of hypercholesterolemia, high TGs, atherosclerosis, CAD, PAD, or recent heart attack or stroke, or on lipid/cholesterol lowering medication regimes at baseline.
Intervention / Exposure	Diet with SFAs content of >10% of total calories from minimally processed, whole food sources, such as full fat dairy products and minimally processed red meat.	Diets with intervention food items that are fortified, enhanced, enriched, identified as highly processed, have altered fat content, such as low or fat free items, added vitamins or minerals not commonly found in their most common minimally processed commercial composition.
Outcome	Changes in blood lipid values used for evaluating cardiovascular health, including TC, LDL-C and subclasses, HDL-C and subclasses, and TGs	Studies without measures of blood cholesterol levels, such as TC, LDL-C and subclasses, HDL-C and subclasses, and TGs.
Study Design Preferences	Randomized control trials	Observational, Systematic Reviews, Narrative Reviews
Size of Study Groups:	>/ = 10	<10
Language	English only	All languages except English
Publication Year Range	2014 – Current	Before 2014

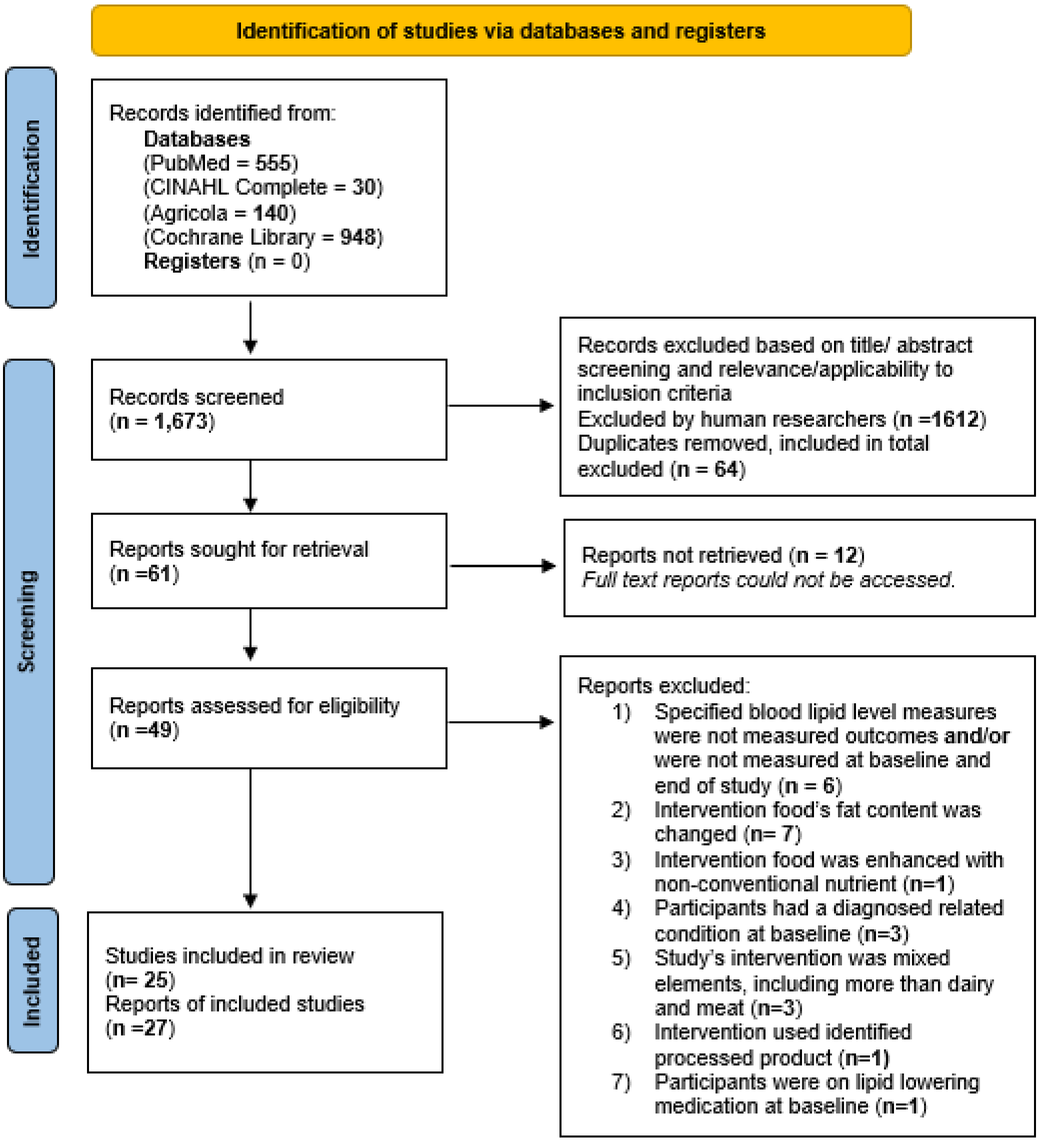

Fig. 2: PRISMA Systematic Review Search Flowchart

3 | RESULTS

After completing the article identification, 27 reports from 25 independent studies with a total of over 2,500 participants were included in this review. A thorough account of each step of the literature search and the results obtained are detailed in Figure 2 according to PRISMA guidelines (18). Brief characteristics of the studies are summarized in Table 5. Results will be narratively discussed in two major sections, studies on the impact of red meat and CVD risk, and the other on full-fat dairy products and their relationship to CVD risk.

Red Meat Research

After searching and filtering reports according to the search strategy given, five studies were used which covered the topic of the impact of minimally processed red meat intake on blood lipoproteins and lipid classes and their relationship to CVD health and risk. All reports reviewed under this subheading had the specific objective of testing various intakes of minimally processed red meat on multiple blood lipoproteins and classes, and accordingly their interventions and results reflected this interest. In the

Table 4. Key Characteristics of Studies

Participants' Ages	Participants' Sex	Study Location
18-84 years old	Men (~42%)	USA (7)
	Women (~58%)	Denmark (3)
		Canada (3)
		Spain (1)
		Iran (3)
		Norway (2)
		China (1)
		Australia (1)
		Switzerland (1)
		England (4)
		Ireland (1)

studies, red meats were defined as regular fat and/or lean cuts of pork and beef, though specific fat content of these cuts was not further provided in most studies. “Lean” and “regular” fat are not standardized industry terms across the world but are in the USA (21). Key characteristics of the studies are listed below in Table 4. Significance is noted when $p < 0.05$, unless otherwise specified. Non-statistically significant findings of the studies are presented primarily in Table 5; some exceptions are given in the main text, however.

LDL-C Responses

Amongst the five studies used in this review, there were mixed results on the impact of lean and regular fat red meats on major blood lipoproteins and lipid species and classes. LDL-C was no exception and is of particular interest to cardiovascular health. In one study by Bergeron et al. (6), researchers determined LDL-C was significantly higher after eating a diet rich in red meat or white (chicken) when compared to a non-meat protein intervention ($p < 0.0001$) independent of SFA level ($p > 0.05$). This study tested diets that were designed to be low (7%) or high (14%) in SFA content and their impact on blood lipid levels in combination with consumption of three different protein sources, red meat, white, and non-meat. Of note, the method by which the SFA content of this study’s dietary interventions was differentiated was primarily through inclusion of “high fat” dairy products and butter. In this study, researchers demonstrated diets with higher SFA content resulted in significantly elevated LDL-C levels, independent of protein source ($p < 0.001$). In this study, increases of LDL-C levels after high SFA (14%) diets resulted in increases in large LDL particles ($p < 0.001$), but small and medium sized LDL particles were unaffected by SFA content or protein source. Researchers did not find significant differences in the number of large LDL particles between red or white meat diets (6). In another study, by Santaliestra-Pasías et al. (22), researchers did not find any significant differences in any blood lipid levels after consumption of lean red or white meat diets ($p > 0.05$).

Three out of the five studies examined in this section analyzed the impact of red meat consumption in the context of a healthful diet, two with a Mediterranean patterned diet, and one with a Nordic patterned diet (8,23,24). The authors tested the hypothesis lean and regular fat beef or pork can be consumed in a healthful diet without causing negative effects to cardiovascular health and can also promote cardiovascular health. In a four-arm crossover trial by Monfort-Pires and colleagues (8), researchers discovered pork consumption in the setting of a diet rich in fiber and micronutrients significantly reduced LDL-C ($p < 0.01$) and LDL:TG ratio (low density lipoprotein to triglyceride ratio) levels. In the context of this study, lean beef consumption was also noted to promote LDL-C reduction, though pork had a stronger effect, $p < 0.05$ and $p < 0.01$, respectively. O’Connor and team (24) highlighted lean red meat consumed within a Mediterranean patterned diet reduced LDL-C by 8% compared to a standard Mediterranean control diet which contained lower amounts of red meat, amounts in line with current Mediterranean diet recommendation for red meat intake. Fleming and colleagues (23) used three different serving sizes of red meat and tested the effect of each serving group/-size on blood lipid levels, also in the context of a Mediterranean patterned diet. In this study, LDL-C was significantly ($p < 0.001$) lowered after all red meat serving groups compared to the control diet, the Average American diet (AAD). The serving sizes were 0.5 oz/day, representing current recommendations for red meat consumption in a Mediterranean Diet Pyramid, 2.5 oz/day, demonstrating the current average American diet consumption of red meats, and 5.5 oz/day, which was demonstrated in a previous study to show heart-protective effects when consumed in a DASH style diet (23). Interestingly, none of the serving groups demonstrated significant dose-response differences affecting LDL-C (23).

HDL-C Responses

Another significant consideration in cardiovascular health is HDL-C, and its subclasses. These will be examined in this section. Bergeron and team (6) detected a modest and similar effect of protein source on upregulation of HDL-C in both red meat and white meat interventions, ($p < 0.004$), particularly in the presence of high SFA content, but this was not the case in the non-meat diet intervention. In the 2022 study by Santaliestra-Pasías and colleagues (22), no statistically significant difference was discovered between consumption of red meat or white meat on HDL-C levels ($p > 0.05$). O'Connor and associates (24) observed both Med-Red and Med-Control diets produced significant differences in HDL-C ($p < 0.05$), but TC:HDL-C did not change in either of the two interventions. Fleming and colleagues (23) noted there were no differences in HDL-C between their interventions with different doses of red meat ($p > 0.05$), but all interventions decreased total HDL particle concentration compared to participants' baseline measurements. After consumption of the highest dose of red meat intake, 5.5oz/-day, a significant reduction in total HDL particles was noted in comparison to the smallest intake of red meat, 0.5 oz/day ($p < 0.05$). There was also a reduction in medium HDL particles following the dose of 0.5 oz/day compared to the highest dose, 5.5oz/day. Montfort-Pires and team (8) observed an increase in HDL particle size, but significant reductions in total HDL-C concentrations after test diets of pork and beef. Both diets in this study also downregulated total HDL-C after two weeks.

Total Cholesterol (TC) Responses

This section will discuss the impact of the various interventions within our selected studies on TC. Amongst the five studies which TC was measured as an outcome, four studies reported statistically significant outcomes (6,8,22-24). Bergeron and team (6) highlighted a significant effect of both protein source (red, white, and non-meat) and SFA content (low, 7%, or high, 14%) individually on TC levels ($P \leq 0.004$), however, TC:HDL-C was not affected by either dietary intervention type. Diets high in SFA content were determined to promote a significant increase in TC levels, regardless of protein source consumed in conjunction. In the same study, both meat diets resulted in statistically significant elevations in TC when compared to the non-meat arm ($p < 0.0001$). There were no significant differences in TC levels between the red meat or white meat intervention ($p < 0.05$). In a 2022 study by Santaliestra-Pasías et al. (22), researchers also observed no significant differences in TC between red or white meat interventions ($p > 0.05$).

Three studies reported blood lipid levels in the context of a healthy diet plus an intervention food. In a study which used a Mediterranean diet and higher red meat intake than current recommendations, Fleming and researchers (23) highlighted regardless of red meat intake and dose, participants' TC levels were significantly reduced post intervention compared to their baseline diets ($p < 0.05$) . Another study which used a similar intervention pattern, O'Connor et al. (24), noted TC levels were decreased more for the intervention with a large dose of red meat, compared to a usual Mediterranean pattern with low red meat intake which was used as a control. A p-value was not specified for significance, however. In this study, ratio of TC:HDL-C did not change in either the intervention or control diet. Monfort-Pires et al. (8) tested the impact of beef and pork plus a healthy Nordic diet on blood cholesterol levels and noted that TC was reduced in both the beef and pork arms, without significant differences between them ($p > 0.05$).

Triglyceride (TG) Response

Three of the five studies used for this section reported no significant responses for TG levels resulting from their interventions (6,22,24). Fleming and team (23) reported no distinction between doses of red meat intake on TG levels, but all diets used in their study (a Mediterranean-pattern diet plus differing doses of red meat and a control standard Mediterranean diet) decreased participants' TG levels compared to their baseline habitual diets ($p < 0.01$). Monfort-Pires and team (8) identified TG levels were significantly reduced only after the pork diet intervention of their study ($p < 0.01$).

Table 5. Red Meat Studies'Characteristic

Author & Year	Design	Bias Rating	Key Findings	Purpose
Bergeron et al., 2019	Two-armed, crossover controlled, randomized, dietary intervention trial.	R (+) V (+)	There were no significant interactions between dietary protein source and SFA level for any of the lipoprotein biomarkers ($P > 0.05$). Concentrations of LDL-C ($p < 0.0001$) was significantly higher after either the red or white meat than after the non-meat diet. Diets high in SFA resulted in higher LDL-C concentrations than diets low in SFA ($p < 0.001$). Increased LDL-C with high SFA diet was associated with higher concentrations of large LDL particles ($p < 0.001$).	To test whether levels of atherogenic lipids and lipoproteins differed after eating diets with high red meat content compared with diets with similar amounts of protein from white meat or nonmeat sources, and if these effects were modified by concurrent intake of high or low SFAs.
Fleming et al., 2021	4-period, randomized, crossover, controlled-feeding study.	R (+) V (+)	TC and LDL-C were significantly lower following the MED0.5, MED2.5, and MED5.5 compared with the AAD ($p < 0.0001$); no differences were observed between the MED diets. A dose–response effect was not detected for increasing lean beef dose on TC, LDL, HDL-C or TG. All diets decreased TGs from baseline ($p < 0.01$).	To examine the dose–response effect of including lean beef [14, 71, 156 g/d/2000 kcal (0.5, 2.5, 5.5 oz/d/2000 kcal)] as part of a healthy Mediterranean-style (MED) diet on blood lipids, lipoproteins, and apolipoproteins compared with an average American diet (AAD) containing $\sim$71 g (2.5 oz) beef/d/2000 kcal.
Monfort-Pires et al., 2023	Four-arm crossover clinical trial.	R (+) V (+)	LDL-C was significantly lowered only after the pork ($p < 0.01$) and beef ($p < 0.05$) test diets. TC was reduced after all test diets, and significant reductions in HDL-C were observed for all test diets, with no differences between them. We found that the pork test diet significantly reduced LDL-C, LDL-TG, as well as total TG.	To investigate whether some of the main meat and dairy products that contribute to animal fat intake in the Norwegian diet (two cheese varieties—Gouda- and Goutaler-type cheeses, pork, and beef meat) could affect health parameters, lipoprotein subclasses, and lipid species in healthy non-obese young individuals.
O'Connor et al., 2018	16-wk randomized, crossover, investigator-blinded, controlled feeding study.	R (+) V (+)	Med-Red decreased TC 3% more than Med-Control. LDL-C decreased by 8% with Med-Red but did not change with Med-Control. Total-C:HDL-C, TG did not change with Med-Red or Med-Control.	To assess the effects of consuming different amounts of lean, unprocessed red meat in a Mediterranean Pattern on cardiometabolic risk factors. We hypothesized that consuming a Mediterranean Pattern would improve CMD risk factors and that red meat intake would not influence these improvements.
Santaliestra Pasías et al., 2022	Randomized cross-over study conducted in three university food halls.	R (+) V (+)	When analyzing both interventions over time (chicken versus Pirenaica breed diets), no statistical differences were observed in any of the body composition or blood sample parameters over time.	To assess the effect of beef or chicken consumption on body composition, fatty acid profile, and cardiovascular (CV) risk indicators in healthy adults.

Dairy Research

Twenty-three reports were used in researching the impact of dairy on CVD and health risk from twenty-one randomized control trial studies. Primary characteristics of the studies are listed below in Table 6.

LDL-C Response

Of the reports assessed and used in this section, LDL-C response differed vastly with some studies (n =11) showing statistically significant results while others did not (n =8). Some reasons for insignificant findings across the studies of this review are described in the discussion section. Brassard et al. (25), observed LDL-C was significantly lower after a cheese intervention diet compared to a butter intervention, but LDL-C levels were higher in both these interventions when compared to carbohydrate, monounsaturated and polyunsaturated-based interventions. In a secondary analysis of the same study, Brassard and team (26) noted LDL-C levels were highest in the butter-rich intervention diet compared to all other interventions ($p < 0.05$). In this analysis researchers also determined baseline LDL-C played a significant role in facilitating LDL-C level changes ($p = 0.02$), regardless of the fat source in question. Researchers also noted participants with high baseline LDL-C levels saw the most significant increase in this cholesterol level following these intervention diets. Engel & Tholstrup (27) identified significantly higher levels of LDL-C after consumption of a butter-rich intervention diet ($p < .005$), particularly compared to a baseline habitual diet ($p < 0.05$) and an olive oil-rich diet ($p < 0.05$). In a study comparing butter-rich and margarine-rich diet interventions, Guggisberg and team (28) observed LDL-C was significantly increased in the butter-rich group when compared to a margarine-rich diet ($p < 0.05$). In another study which compared interventions with 50g daily of butter, olive oil, and coconut oil, Khaw and colleagues (29) reported LDL-C concentrations were increased the most in the butter intervention ($p < 0.0001$) compared to both coconut oil and olive oil interventions. Panth and researchers (30) investigated the impact of different SFA sources (40g of butter, 40g unrefined coconut oil, and 40g of lard) on post meal blood lipid levels. In this study researchers highlighted significant changes in LDL-C at selected time intervals post consumption of each fat source, with the change from the butter intervention being the most distinct ($p < 0.01$). Vasilopoulou and colleagues (9) showed that in comparison to a SFA modified diet, a diet rich in dairy produced a significant increase in the LDL-C:HDL-C ratio ($p = 0.04$). Hyde et al. (31) also identified a significant difference in LDL-C concentrations after a butter-rich intervention when consumed in combination with either a low carbohydrate/high fat or high carbohydrate/low fat intervention versus a palm stearin rich intervention ($p = 0.003$ and $p = 0.002$, respectively). This increase in LDL-C primarily resulted in an increase in large LDL particles.

HDL-C response

Of the reports analyzed in this review, six studies showed statistically significant results. In a follow-up analysis of the landmark study, the Tehran Lipid and Glucose Study, Hosseinpour-Niazi and team (32) concluded intakes of butter were negatively/inversely related to HDL concentrations (OR: 2.03, 95% CI: 1.20–3.41). One study by Engel & Tholstrup (27) demonstrated in two diet interventions with equal amounts of fat either as olive oil or butter, a butter-rich intervention resulted in a 3.6% increase ($p < 0.01$) in TC:HDL ratio compared to the olive oil rich intervention. In this same study, researchers also noted no statistically significant change in HDL-C between the butter and olive oil trials. Khaw and colleagues (29) compared a butter, olive oil, and coconut oil intervention, and also reported a significant increase in TC/HDL-C ratio after the butter intervention compared to a coconut oil (+0.36, 95% CI 0.18 to 0.54) and an olive oil intervention (+0.22, 95% CI 0.04 to 0.40). Brassard and team (2017) compared interventions rich in butter, cheese, and carbohydrates, and determined there was a similar impact of cheese and butter on HDL-C, and both diets resulted in significantly higher HDL-C levels than after a carbohydrate-rich diet ($p < 0.05$). In a study which compared interventions of two different types of cheese, Gouda or Goutaler-style, in combination with a healthy Nordic diet, Monfort-Pires and team (8) observed HDL-C was significantly lowered after both diets ($p < 0.05$), with no differences between them. In this same study, both diets upregulated HDL size. The selected cheeses in combination with the healthy Nordic diet were observed to decrease HDL-C after two weeks of the intervention. In 2019, Hansson and researchers (33) compared interventions of sour cream, butter, cheese, and whipped cream, and noted the sour cream intervention produced the most significant increase in serum HDL-C-iAUC0-6h of these ($p < 0.01$).

Total Cholesterol Responses

Six reports used in this section presented statistically significant results on the response of total cholesterol post a full fat dairy intervention. Chiu and team (34) evaluated the impact of full fat versus low fat dairy products in the context of two DASH-patterned diet interventions. This study reported both interventions resulted in significantly reduced TC when compared to a control diet similar to an average AAD ($p = 0.02$). A 2015 study by Engel & Tholstrup (27) compared two intervention trials of butter and olive oil, and observed TC was significantly higher in the butter period ($p < 0.005$) than in either a 2-week habitual diet run-in period or olive oil-rich intervention. This study concluded a diet supplemented with moderate amounts of butter resulted in a 4.2% ($p < 0.05$) higher TC concentration when compared to an olive oil rich intervention containing equal fat content. In 2022, Guggisberg and team (28) reported TC was significantly increased in a butter-rich intervention compared to a margarine-rich intervention ($p < 0.05$). Roy et al. (35) demonstrated a diet with elevated dairy content resulted in a significantly increased TC concentration compared to participants' baseline diets and also post a control diet without dairy. Liang and colleagues (36) examined the impact of an intervention rich in butter and olive oil on participants of different ethnic groups, East Asian Chinese and European Caucasians. In this study, researchers presented a 5.0% decrease in TC when participants consumed olive oil compared to butter. O'Connor et al. (37) examined the impact of cheese in its melted and unmelted forms on blood lipid levels and reported there was a statistically significant difference in TC after six weeks of consumption of melted and unmelted forms of the same cheese ($p = 0.027$).

Triglyceride Response

Eight reports analyzed in this section demonstrated statistically significant results. In 2017, Brassard and crew (25) investigated five different dietary interventions (butter, cheese, MUFA-rich, PUFA-rich, and carbohydrate-rich) for their effects on blood lipid levels. Of the interventions, researchers observed the cheese intervention resulted in higher serum TGs compared to the PUFA-rich and butter-rich interventions ($p < 0.05$, respectively), but this was not the case when compared to the MUFA and carbohydrate-rich interventions ($p > 0.05$). In this same study, researchers reported butter was correlated to reduced serum TGs compared to the carbohydrate-rich trial ($p < 0.05$), but not compared with the MUFA and PUFA-rich intervention arms ($p < 0.05$). In contrast, Chiu and colleagues (2016) noted a DASH style diet with full fat dairy products resulted in significantly reduced plasma TGs when compared to a similar DASH-style diet with low-fat dairy products as the main dairy source ($p = 0.017$).

Drouin-Chartier et al. (38) investigated the impact of three different dietary interventions (cream cheese, cheddar cheese and butter) on TG levels at multiple timeframes postprandial. This study observed at eight hours post consumption of an intervention meal, all meals resulted in non-statistically different TGs levels in participants; there were some results which were distinct, but most did not reach statistical significance, in the timeframe between consumption and eight hours post. At two hours, the cream cheese intervention induced a larger change in TG levels compared to butter and cheddar cheese ($p = 0.02$ and $p = 0.0004$). Cheddar and butter produced a similar effect compared to each other. At six hours, postprandial TG levels were lower for the cream cheese intervention than by the cheddar cheese diet ($p = 0.004$).

Another study investigated the impact of multiple dairy products (sour cream, hard cheese, whipped cream, and butter) on postprandial TG response (33). Researchers from this study reported intake of sour cream produced a significantly larger serum TG response at 6 hours than all other dairy products ($p < 0.05$). Of note, this study reported mean differences in TG response of 61%, 53%, and 23% between sour cream and whipped cream, sour cream and butter, and sour cream and cheese, respectively. Hosseinpour-Niazi and co-researchers (32) concluded intake of butter was positively associated with TG concentrations (OR: 2.03, 95% CI: 1.20–3.41).

Table 7 Dairy Studies' Characteristics

Author & Year	Design	Bias Rating	Key Findings	Purpose
Brassard et al., 2017	A multicenter, crossover, randomized controlled trial; single-blind crossover study design.	**R** (+) **V** (+)	Serum HDL-C concentrations were similar after the cheese and butter diets but were significantly higher ($P < 0.05$ for both) than after the carbohydrate diet. After the cheese diet, LDL-C concentrations were significantly lower than after the butter diet but were higher than after the carbohydrate, MUFA, and PUFA diets. LDL-C concentrations after the butter diet were significantly higher than after all other diet interventions. The baseline LDL-C concentration significantly modified the LDL-C response to treatment (p-interaction = 0.02). Cheese led to higher serum TG concentrations compared with the effects of butter and PUFAs ($p < 0.05$), but not compared with the effects of MUFAs or carbohydrates. Butter was associated with reduced serum TGs ($p < 0.05$) compared with carbohydrates intake but not compared with the effects of MUFAs and PUFAs.	To compare the impact of consuming equal amounts of SFAs from cheese and butter on cardiometabolic risk factors.
Brassard et al., 2018	A multicenter, crossover, randomized controlled trial.	**R** (+) **V** (+)	No significant differences were observed in HDL-C concentrations after consumption of the 4 high-fat diets. BUTTER increased serum LDL-C concentrations compared with the other diets except when compared to CHEESE ($p = 0.066$).	A predefined secondary analysis of a previously published trial, examined how diets rich in SFAs from either cheese or butter influence HDL-mediated cholesterol efflux capacity (CEC), compared with diets rich in either MUFAs or PUFAs.
Chiu et al., 2016	3-period randomized crossover study	**R** (+) **V** (+)	For the primary comparison of the DASH and HF-DASH diets, the latter resulted in significantly lower plasma TG ($p = 0.017$) and significantly higher LDL peak particle diameter ($p < 0.001$). Both the DASH and HF-DASH diets significantly reduced TC compared with the control diet. Except for lower TC, none of the lipid and lipoprotein measurements differed significantly between the HF-DASH and control diets after Bonferroni correction.	The study was designed to test the effects of substituting full-fat for low-fat dairy foods in the DASH diet.
Drouin-Chartier et al., 2017	Single-center, randomized, crossover controlled trial.	**R** (+) **V** (+)	The cream cheese, cheddar cheese, and butter induced similar increases in TG concentrations at 4 hours compared with baseline values ($p = 0.9$). At 2 hours, the cream cheese induced a greater increase in TG concentrations than the butter ($p = 0.002$) and the cheddar cheese ($p = 0.0004$), whereas the cheddar and the butter induced a similar TG response ($p = 0.9$).	Compare the impact of dairy fat provided from firm cheese, soft cream cheese, and butter on the postprandial response at 4 h and on the incremental area under the curve (iAUC) of plasma TGs.
Engel & Tholstrup, 2015	Randomized, controlled, double-blind, crossover intervention study with a 2-wk run-in period of the habitual diet.	**R** (+) **V** (+)	TC and LDL-C concentrations were significantly higher in the butter period than in the run-in period ($p < 0.005$ and $p < 0.05$, respectively) and olive oil period. There was no difference between butter and olive oil periods for HDL-C concentrations, but concentrations were significantly higher in the butter period than in the run-in period. The ratio of TC:HDL-C was significantly higher in the butter period than in the olive oil period ($p < 0.01$).	Investigate the effect of a diet with a moderate amount of butter or refined olive oil, with equal amounts of fat content, and habitual diet measured in the run-in period on risk markers of CVD and fasting serum lipids.
Guggisberg et al., 2022	Randomized, controlled, double-blind, three-arm, parallel-group intervention.	**R** (+) **V** (+)	TC was significantly increased in the rTFA group (0.44 mmol/L) compared to the wTFA group. LDL-C was significantly increased in the rTFA. HDL-C was not significantly ($p > 0.05$) increased. TG were not significantly ($p > 0.05$) increased in the rTFA group. A small but significant increase in TC and LDL-C was observed in the group with the butter diet compared to the groups with the margarine diets.	To investigate the health effects of trans fatty acid intake from industrial and ruminant sources.
Hansson et al., 2019	Randomized controlled cross-over study.	**R** (+) **V** (+)	Intake of SC induced a significantly larger serum TG-iAUC0–6h than all other dairy products ($p < 0.001$ for SC compared with WC and SC compared with B; $p = 0.05$ for SC compared with C). The mean TG-iAUC0–6h for SC was 61%, 53%, and 23% larger compared with intake of WC, B, and C, respectively. There was a significant meal effect on the postprandial HDL-C-iAUC0–6h ($p = 0.02$). Intake of SC induced a larger serum HDL-C-iAUC0–6h compared to C ($p = 0.01$). There was no significant meal effect on the postprandial TC-iAUC0–6h ($p = 0.37$) or LDL-C-iAUC0–6h ($p = 0.21$).	To investigate the effect of meals with similar amounts of fat from different dairy products on postprandial TG concentrations over 6 h in healthy adults.
Hosseinpour-Niazi et al., 2016	Randomized controlled secondary analysis of the Tehran Lipid and Glucose Study.	**R** (+) **V** (+)	Intake of butter was positively associated with TG concentrations and negatively with HDL-C concentrations. Non-consumption of butter (95% CI: 0.56–0.97) was associated with lower MetS risk, as compared to consumption.	To investigate the association between hydrogenated vegetable oils (HVOs) and non-hydrogenated vegetable oils (non-HVOs) and butter and the metabolic syndrome (MetS) after 3 years of follow-up in adults.
Hyde et al., 2021	Randomized, controlled-feeding, cross-over study.	**R** (+) **V** (+)	Compared to PS, LDL-C in Butter was 13.4% higher in the LC/HF group ($p = 0.003$) and 10.8% higher in the HC/LF group ($p = 0.002$).	To compare the consumption of palm stearin versus butter on circulating cholesterol responses in the setting of both a low-carbohydrate/high-fat and high-carbohydrate/low-fat diet.
Khaw et al., 2018	Randomised clinical trial.	**R** (+) **V** (+)	LDL-C concentrations were significantly increased on butter compared with coconut oil ($p < 0.0001$) and olive oil ($p < 0.0001$). Butter significantly increased the TC/HDL-C ratio compared with coconut oil.	To compare changes in blood lipid profile, weight, fat distribution, and metabolic markers after four weeks of consumption of 50 g daily of one of three different dietary fats: extra virgin coconut oil, butter, or extra virgin olive oil.
Kjølbæk et al., 2021	Randomized crossover trial.	**R** (+) **V** (+)	Postprandial TGs increased after MCI Gel compared with Cheese and Hom. Cheese, respectively (both $p \leq 0.05$). HDL-C and LDL-C showed no differences between meals.	To investigate acute 8-h postprandial lipid, glycemic, and appetite responses after intake of isoenergetic

				dairy meals with different matrixes, but similar nutritional composition.
Liang et al., 2023	Two-arms crossover randomized control trial.	**R** (+) **V** (+)	A lower TC (−5.0%) and LDL-C (−7.0%) was observed when consuming EVOO instead of butter.	To evaluate the impact of supplementing extra virgin olive oil (EVOO) on markers of cardiovascular risk among East Asian Chinese and European Caucasians.
Li et al., 2018	Pair-wise intervention study.	**R** (+) **V** (+)	No significant within- or between-group differences were observed in TG, TC, LDL-C, HDL-C ($p > 0.05$).	To compare the impact of whole milk supplementation on gut microbiota and cardiometabolic biomarkers between lactose malabsorbers and absorbers.
Markey et al., 2021	Acute randomized, double-blind, sequential-meal, crossover dietary study.	**R** (+) **V** (+)	For the TG response, there was a 2.8% higher iAUC after the modified dairy compared with the control breakfast meal (0–330 min) ($p = 0.009$). No other pre- or post-lunch differences in AUC or iAUC were evident between the modified and control dairy meals ($p > 0.01$).	The effects of sequential high-fat mixed meals rich in fatty acid (FA)–modified or conventional (control) dairy products on postprandial FMD (primary outcome) and systemic cardiometabolic biomarkers in adults with moderate cardiovascular risk.
Mohammadi-Hosseinabadi & Nasrollahzadeh, 2022)	Randomised, not blinded, crossover, clinical trial.	**R** (+) **V** (+)	The plasma LDL-C concentrations were not different after consumption of the two diets (treatment × time, $p = 0{\cdot}092$). There were no significant differences in plasma HDL-C and TAG concentrations, or the ratio of TC: HDL-C between the two diets.	To evaluate the cardiovascular health-related effects of consuming ghee in the usual diet.
Monfort-Pires et al., 2023	Four-arm crossover clinical trial.	**R** (+) **V** (+)	LDL-C was significantly lowered only after the pork ($p < 0.01$) and beef ($p < 0.05$) test diets. TC was reduced after all test diets, and significant reductions in HDL-C were observed for all test diets, with no differences between them. TG levels were significantly reduced only after the pork test diet ($p < 0.01$). We found that the pork test diet significantly reduced LD-C, LDL-TG, as well as total TG in lipoproteins.	To investigate whether some of the main meat and dairy products that contribute to animal fat intake in the Norwegian diet (two cheese varieties—Gouda- and Goutaler-type cheeses, pork, and beef meat) could affect health parameters, lipoprotein subclasses, and lipid species.
O'Connor et al., 2024	Parallel-arm design with four diet intervention groups.	**R** (+) **V** (+)	Post-intervention, there were significant differences in Δ TC ($p = 0.027$), and TG ($p = 0.049$) concentrations. Analyses indicated significant differences in absolute change from pre-post intervention between group A and group B for TC ($p = 0.008$), and TG ($p = 0.016$) respectively. No difference was observed between the groups for HDL, LDL or VLDL cholesterol.	Examine the impact of the state of the cheese matrix (unmelted, melted, or deconstructed state) on markers of cardiometabolic health.
Panth et al., 2020	Randomized, cross-over, single-blinded design study with three experimental test days separated by at least a week of washout period.	**R** (+) **V** (+)	There were time-dependent changes in TG concentrations after the CB, BB, and LB ($p < 0.001$ for all). The net AUC for the TG postprandial change was significantly higher after consumption of the BB ($p < 0.01$) and the LB ($p < 0.01$). TG levels returned to baseline 6 hours after the consumption of the CB, but TG levels remained significantly higher than baseline values 6 hours following consumption of the BB and the LB. When comparing the three test biscuits, no significant differences were observed in HDL-C and TC change net AUC.	To evaluate the differential effects of foods containing SCFA (butter), MCFA (coconut oil), or LCSFA (lard) on postprandial blood lipids.
Ranjbar & Nasrollahzadeh, 2024	Randomized, crossover trial.	**R** (+) **V** (+)	Compared to the period of full-fat yogurt, consumption of low-fat yogurt and butter tended to increase in plasma TC ($p = 0.075$), non-HDL-C ($p = 0.056$), and the TC to HDL-C ratio ($p = 0.095$). There were no differences in plasma TG, LDL-C, and HDL-C levels between the two treatment periods.	To compare full-fat yogurt with low-fat yogurt and butter for their effects on cardiometabolic risk factors in healthy individuals.
Raziani et al., 2016	12-wk randomized parallel intervention.	**R** (+) **V** (+)	Analyses showed no significant differences in LDL-C or HDL-C between the REG and RED diets or between the REG and CHO diets (all $p \geq 0.05$).	To compare the effects of regular-fat cheese with an equal amount of reduced-fat cheese and an isocaloric amount of carbohydrate-rich foods on LDL-C and risk factors for the metabolic syndrome (MetS).
Roy et al., 2019	Randomized controlled crossover design.	**R** (+) **V** (+)	TC significantly increased from baseline and demonstrated an elevation during the high-dairy condition when compared against the no-dairy control ($p < .05$). LDL-C approached a significant increase from baseline in the high-dairy phase and was greater than the no-dairy control, promoting the TC increase ($p = .07$) as HDL-C and TG did not change.	To determine if a dietary intervention that includes whole milk and full-fat dairy products reduces arterial BP in adults with elevated BP.
Sciarrillo et al., 2019	Four randomized meal trials.	**R** (+) **V** (+)	LDL-C, HDL-C, and TOTAL-C revealed no time effect, meal effect, or time–meal interaction (all $p > 0.05$). Meal trials did not differ regarding LDL-C and HDL-C total AUC, or incremental AUC (all $p > 0.05$). One-way ANOVA revealed that HDL-C and TOTAL-C peak, and time to peak were not different across meal trials ($p > 0.05$).	To determine the postprandial response in TGs to four dietary fat sources in adults.
Vasilopoulou et al., 2020	A double-blind, crossover, randomized controlled proof-of-concept study.	**R** (+) **V** (+)	There was no significant Δ in serum TC between diets ($p = 0.08$). There was no evidence of a difference in Δ in HDL-C between the 2 diets. No significant treatment effect was observed for any other component of the lipid profile measured ($p > 0.05$).	To determine the effects of consuming SFA-reduced, MUFA-enriched (modified) dairy products, compared with conventional dairy products (control), on the fasting cholesterol profile, endothelial function assessed by flow-mediated dilatation and other cardiometabolic risk markers.

Panth et al. (30) investigated the impact of three different fat sources (butter, coconut oil, and lard) on postprandial blood cholesterol levels. In this study researchers reported serum TG levels were highest three hours after consumption of the interventions, and the level of increase was most significant in both the butter and lard interventions compared to the coconut oil intervention ($p < 0.01$). Another finding of note from this study was researchers discovered TG levels were significantly elevated at six hours post consumption of the butter and lard intervention compared to the coconut oil intervention ($p < 0.05$). Lastly, O'Connor et al. (37) researchers demonstrated consuming melted cheese compared to unmelted for six weeks resulted in significantly different TG concentration ($p = 0.049$).

Quality Assessment/Risk of Bias

All reports used in this review were from randomized controlled trials (RCTs). All reports received a positive (+) rating per the Academy of Nutrition and Dietetics Quality Criteria Checklist, indicating strong study design, minimal risk of bias in data collection and reporting, and appropriate analysis of results (20).

4 | DISCUSSION

Red Meat Research

The precise mechanisms of how LDL-C, HDL-C, TC, and TG interact to promote the development of CVDs are under debate (39-47). Most current research argues; however, elevated total LDL-C and low HDL-C levels in general promote the development of CVD (4,5,16,17,41-43,48-50). High TGs are most associated with elevated CVD risk, though only one piece of the whole picture of CVD (39,43,44,46) TC is a measure of all the cholesterol types in a person's blood. Though measures of TC may assist in identifying diets which promote elevated cholesterol levels, as well as increased CVD risk, this measure does not distinguish between cholesterol types (17,48,51). TC is still a clinically significant measure however (48,51). In this section the implications of red meat intake on the blood cholesterol levels of LDL-C, HDL-C, TC, and TG is explored.

LDL-C has been identified as a key deliverer of cholesterol to the arterial walls and has been shown to promote the growth of plaques in arteries which can impact blood flow throughout the body and promote multiple CVDs (40,41,45). The negative effect of elevated total LDL-C on cardiovascular health is a long-established effect (40-42,45,47). In three studies which analyzed red meat consumption in combination with an overall healthy diet, researchers demonstrated LDL-C, TC and TG levels were significantly reduced across all intervention groups when compared with participants' baseline diets or the studies' control diets (8,23,24). All three studies included red meat in amounts above the current Mediterranean Pyramid guideline recommendation of 2.5 oz/day. The findings suggest minimally processed, lean red meat in amounts larger than in current Mediterranean Pyramid guidelines may safely be incorporated into a diet which supports overall cardiovascular health in the general population. Multiple studies have shown a Mediterranean diet pattern substantially promotes cardiovascular health, and one of the primary pathways by which this diet improves cardiovascular health is by decreasing LDL-C and increasing HDL-C (42,52,53). Fleming and team (23) and O'Connor and colleagues (24) demonstrated the LDL lowering effects of the Mediterranean diet pattern were not significantly impacted by inclusion of lean red meat in various amounts above current recommendations. The findings of this research suggest further analysis of the cardio-protective elements of a Mediterranean diet pattern, and further research into healthful doses of red meat intake above current guidelines is needed.

Another recognized diet pattern which may aid cardiovascular health is the Nordic Diet (54). Montfort-Pires and team (8) used this diet to investigate the impact of red meat plus the Nordic Diet on blood lipid measures. This study also reported significant decreases in LDL-C in both interventions of red meat, one of pork and one with beef. Because of how common pork and beef consumption are in the USA's diet, further exploration of this finding may be of public interest (10,55). Of note, this study also observed the pork diet was the only intervention which promoted a statistically significant decrease in TG levels, as well as overall LDL-C. Further research into the impact of beef and pork consumption individually within a healthful diet is warranted.

Two studies determined most blood lipoproteins and lipid class levels were not significantly impacted by source of protein, red or white meat, except in addition to elevated overall SFA content (6,22). Results noted no significant interactions between SFA content and protein source, suggesting there were not inherent factors which disposed red meat to increasing cholesterol content apart from overall SFA content (6). Though the current Dietary Guidelines for Americans 2020-2025 do not distinguish between red meats and white for meat intake, many health professionals preferentially recommend a higher intake of poultry and plant-based proteins for meeting daily protein needs, compared to red meat, primarily based on sources of SFA content (15,42,56-58). Bergeron and team (6) further reported similar and higher LDL-C levels resulted from both the white and red meat diets when compared to a non-meat intervention. Of importance, Santaliestra-Pasías and associates (22) did not reach statistical significance in their research due to insufficient sampling. This impedes the generalizability of these findings in current research. Overall, the findings suggest lean cuts of red meats and poultry may be consumed equally in a diet which promotes cardiovascular health.

In comparison to LDL-C, HDL-C is often considered the "good" cholesterol because of its cholesterol lowering effects in the body (42,47). Amongst the studies reviewed, there were a few statistically significant changes in HDL-C. Monfort-Pires and colleagues (8) tested pork and beef consumption within a Nordic patterned diet. The researchers reported significant decreases in HDL-C after both interventions of red meat. Traditionally it has been considered desirable for HDL-C to be elevated, and LDL-C to be maintained at a lower metric to support cardiovascular health and reduce the risk of cardiovascular incidence and disease (42,47,50,59). Recent research has suggested there may be a U-shaped relationship between HDL-C and CVD risk, where elevated HDL-C may not always be desirable (47,49,50). Further research into this relationship is needed. Bergeron and team (6) stated there was a minor increase in HDL-C after diets of red meat and white meat, particularly after the intervention arms where SFA content was high (14%), but not after the non-meat intervention. Statistical significance for this effect was not given, however. No significant differences in HDL-C were detected after studies by O'Connor et al. (24) or Santaliestra-Pasías et al. (22). The study by Fleming and partners (23) reported a modest increase in HDL-C after the highest red meat intake compared to the lowest intake for their interventions of red meat plus a Mediterranean diet. Currently, it is unclear if red meat intake has a significant positive influence on HDL-C. The impact of red meats consumption on HDL-C warrants further research.

A new direction for analysis on the impact of blood lipoproteins and lipid classes on cardiovascular health may be discovered by looking into the subclasses of LDL-C, HDL-C, and TGs. Some evidence promotes the idea that different subclasses of the major blood cholesterols (LDL-C, HDL-C, and TGs) may provide differences in the speed at which CVD develops (39,41,43,44,46,51,60). Further explanation of cholesterol particle subclasses may yield insight into the impact of diet and the SFA content of different foods on cardiovascular disease and health.

Dairy Research

A co-objective of this review was to examine the impact of a variety of full fat dairy products, such as yogurts and cheeses, on blood lipoproteins and lipid classes; however, fourteen out of twenty-two studies analyzed in this section used butter in their interventions, and most used butter as the main comparison intervention. Discussion of butter, along with other dairy products is expressed here.

Cow's milk is the most common milk used for human consumption in the world (61). According to the International Dairy Federation, fluid cow milk is the most consumed dairy product in the world (61). Currently an estimated 80% of the world's population consumes milk and dairy products on a regular basis (62). Despite the prevalence of fluid milk consumption globally, research into fluid milk's impact on cardiovascular health, particularly blood cholesterol, is limited. A handful of studies were identified which met the inclusion criteria and used fluid milk (34,35,63). The authors of the studies did not find significant differences in LDL-C, HDL-C, TC or TG after consumption of fluid whole milk. All studies included whole milk in addition to either the participants' normal diet or milk was consumed in combination with a DASH patterned diet intervention. The findings suggest whole milk may not negatively impact blood cholesterol levels and can be included in healthful diets which promote cardiovascular health in the general population.

One major product which is extracted from whole milk is butter. Butter is an important part of multiple cultures across the world. Recommendations for limited butter intake have been advocated for decades (27,36,42,64,65). The most common argument for modest butter consumption has been primarily based on the hypothesis all foods rich in SFA promote increased LDL-C, one of the most recognized disease-promoting factors impacting cardiovascular health (27,36,42,65). Butter is comprised of approximately 70% SFAs (66). The findings of this review support the effect of butter on increasing total LDL-C levels. Multiple researchers noted butter significantly elevated LDL-C in comparison to interventions which used margarine, palm stearin, coconut or olive oil, and a few cheeses (25,27-30,32,36). The impact of butter on LDL-C is perhaps one of the most well studied dairy products in relation to blood cholesterol levels in the history of nutrition research (42). Overall, butter has been identified as a potent dietary factor which impacts cardiovascular health, and moderation in its consumption is advisable according to this research.

Current guidelines for butter intake recommend sparing usage and heartily recommend trading as much SFA-rich butter for polyunsaturated and monounsaturated-rich oils, such as olive and nut oils (15,64). In relation to other blood cholesterol levels, there are fewer clear results on the impact of butter. In this review, seven studies agreed butter intake increased TC levels, while almost an equal number (n =5) did not find a statistically significant difference. In relation to butter's impacts on TG levels, some studies agreed (n =4) TG levels were significantly increased post consumption of a butter rich diet; however, the majority (n =11) did not find a significant impact. A few studies (n =4) highlighted statistically significant impact of butter on HDL-C but most did not (n =10). Two of the four studies which identified significant differences in HDL-C noted butter intake was negatively associated with HDL-C. This finding suggests elevated butter intake may decrease HDL-C concentrations in the blood. Because of the role of HDL-C in promoting cardiovascular health, further research into effects of butter on HDL-C may be warranted.

The impact of cheese had variable results for LDL-C, HDL-C, TC, and TG levels. A total of twelve reports examined the impact of cheese on various blood lipoproteins and lipid classes. Amongst the studies which listed LDL-C as an outcome, four studies reported significant findings and six reported non-significant findings for the impact of a diet rich in cheese on LDL-C concentrations (8,9,25,26,33-35,67,68). An interesting result by Brassard and team (25) demonstrated a cheese-rich intervention resulted in LDL-C levels which were elevated compared to interventions using PUFAs, MUFAs, and carbohydrates, but were lower than the intervention which included elevated butter intake (25). Two other studies, which had LDL-C as an outcome, demonstrated LDL-C was also elevated compared to other non-dairy diet interventions, indicating cheese appears to have a distinct impact on LDL-C levels, but the effect of this food item may not be the same as butter (8,25). Based on the findings of this review, it remains unclear whether cheese has a positive or negative effect on LDL-C levels; however, the lack of a clear direction on the relationship of cheese to LDL-C levels may indicate that within an overall healthy diet pattern, full fat cheese does not negatively impact cardiovascular health.

Two studies reported significant findings while six noted non-significant findings for the impact of a diet rich in cheese on HDL-C concentrations (7,9,26,34,35,37,67,68). Brassard and colleagues (25) showed HDL-C, after a cheese intervention, was elevated similar to butter, and both the butter and cheese rich intervention produced higher HDL levels than a carbohydrate-based intervention. The other study which demonstrated statistically significant results after a cheese-rich intervention, reported HDL-C was significantly lowered as a result of the intervention which included a Nordic diet and elevated cheese intake (8). Between the opposite results of the two studies and the insignificant results of the six other studies used in this section, results of this review suggest intake of full fat cheese within an overall healthy diet may not have a negative relation to HDL-C levels, and may be consumed in a diet which promotes cardiovascular health.

Several studies reported results for the impact of a cheese rich intervention on TC with an equal amount demonstrating statistically significant results as those that did not (n =4 for both) (8,9,33-35,37,67,68). Roy and crew (35) demonstrated TC was increased from participants' baseline during the high-dairy intervention compared to a no-dairy intervention ($p < 0.05$). This finding suggests dairy intake does have a distinct effect on TC; however, the direction of this relationship could not be determined. Another study reported reduced TC post an intervention which used a Nordic diet with high cheese content (8). This finding suggests cheese may not negatively impact overall cholesterol levels. A final and novel result noted statistically significant differences in TG levels between two diets rich in the same cheese, where one cheese was melted, and the other was not (37). This study reported TGs were significantly increased after the intervention with melted cheese compared to cheese eaten unmelted ($p < 0.008$). The impact of heating dairy products and the absorption of lipids after consumption of the products are warranted to confirm this effect.

Results on the impact of full fat cheese consumption on TG levels produced variable results with most studies (n =7) showing statistically significant results, and a few not reaching statistical significance (n =4) (7-9,25,33-35,37,38,67,68). Three studies demonstrated cheese intake increased TGs while four showed cheese either had a neutral or opposite effect on total TGs post interventions rich in cheese. Brassard and team (25) reported TG levels were significantly higher post a cheese rich intervention when compared to a butter and PUFAs rich interventions, but not compared to MUFA or carbohydrate rich interventions. This unique finding suggests cheese intake can increase TG levels even more than butter. In a study by Drouin-Chartier et al. (38), researchers detected cheese and butter produced similar increases in TGs at two hours, and all diet interventions (cream cheese, cheddar cheese, and butter) had the same TG response at four hours post consumption. The results of this study suggest cheese and butter have similar responses on TG levels. The mix of significant, non-significant, and opposite findings across the studies which explored the impact of cheese consumption on the various blood cholesterol levels highlight the complexity of assessing individual food items within a comprehensive diet.

Some studies combined multiple dairy products in their interventions to distinguish the impact of "high" fat content from full fat dairy sources (without distinction of each product's individual impact) compared to lower fat interventions which used "low" fat or no dairy products (7,9,34,35,65). There were characteristically varied results on the impact of higher dairy fat intake versus low dairy fat intake on blood lipoproteins and lipid classes. One study demonstrated TC was significantly higher after a high fat dairy intervention compared to a low-fat dairy intervention (35). Studies by Ranjbar & Nasrollahzadeh (65) and Vasilopoulou et al. (9) lean towards agreement with this finding; however, both studies' results did not reach statistical significance on this factor ($p = 0.08$, respectively). Chiu and colleagues (34) demonstrated a significant decrease in TC, but this effect was in the setting of a DASH patterned diet, which has multiple components that have been identified to promote cardiovascular health. The findings suggest higher dairy fat intake does in fact tend to impact several blood cholesterol levels; however, the effect of elevated dairy fat consumption on reducing or increasing cholesterol levels can be highly variable. Some reasons for variability in results from whole food diets are discussed further in the strengths and limitations section.

Some research has demonstrated a positive effect of yogurt intake on health, including the impact of yogurt on cardiovascular health (69-71). Three studies in this review assessed the impact of yogurt intake on cardiovascular health with two out of the three using yogurt in combination with other full fat dairy products, such as whole milk and cheese (34,35,65). Researchers reported conflicting results in response to their interventions. Chiu and associates (34) demonstrated a DASH patterned diet intervention with full fat dairy products, including yogurt, produced significantly lowered TC compared to a standard low-fat dairy DASH diet. This finding suggests full fat yogurt may be included in a diet which supports cardiovascular health. It also suggests the cardiovascular health promoting components of the DASH diet are not negated by inclusion of full fat dairy products. Roy and associates (35) used a multiproduct intervention which included yogurt for their research, and reported no significant change in LDL-C, HDL-C, and TG. These researchers did find a statistically significant change in TC, which was elevated in the high dairy fat intervention compared to the no-dairy control. This finding agrees full fat dairy produces variable results on blood lipoproteins and lipid classes; however, full-fat dairy may be included in an overall diet which promotes cardiovascular health. The last study of this section, Ranjbar & Nasrollahzadeh (65), highlighted total plasma cholesterol increased in the intervention which used low-fat yogurt combined with butter ($p = 0.056$), compared to the intervention which used full fat yogurt and with no additional butter consumption. This finding lends more evidence to the effect of butter on cholesterol classes compared to yogurt's impact. Further research on the specific impact of various yogurts, both full fat and low fat, is warranted.

In 2019, Hansson and team (33) investigated the impact of sour cream and whipped cream on blood cholesterol levels. In this study, researchers highlighted that intake of sour cream promoted significantly higher TG levels compared to interventions with whipped cream, cheddar cheese, and butter. Consumption of sour cream also promoted significantly increased HDL-C concentration when compared to cheese ($p < 0.01$). This study did not find statistical significance for sour cream impact on LDL-C or TC. Due to the impact of elevated TGs on CVD and the positive effect of increased HDL-C in promoting improved cardiovascular health, the effects of sour cream in this study can support a mildly favorable effect of sour cream intake on blood lipid levels; however, further research into this effect is needed (42,47,50,72). In this same study by Hansson et al. (33), researchers reported unsweetened whipped heavy cream produced the smallest increase in blood TG levels when compared to butter, cheese, and sour cream, and had the lowest TG response at the four to six hour postprandial range, the region most correlated to increased CVD risk. This finding suggests a positive effect of unsweetened whipped heavy cream consumption on cardiovascular health; however, further research on this dairy product is needed to confirm this effect. According to the results of this study, moderate sour cream and whipped heavy cream may be incorporated into a diet which promotes overall cardiovascular health.

One study investigated the impact of ghee and cream cheese each (32,38). In the study which investigated the impact of ghee intake on CVD, Mohammadi-Hosseinabadi & Nasrollahzadeh (73) reported no significant differences in LDL-C, HDL-C, and TG levels between participants who consumed ghee compared to those who did not. Considering how prevalent ghee is in Indian cuisine, further research into the impact of ghee on cardiovascular health is needed (73,74). Finally, Drouin-Chartier and colleagues (38) noted cream cheese intake was significantly correlated to elevated TG concentrations compared to the dairy products of cheddar cheese and butter at two and four hours postprandial, suggesting limited cream cheese intake is advisable. With only one study on the impact of ghee and cream cheese individually on blood cholesterol levels, further research on these dairy products is earnestly warranted.

Quality Assessment/Risk of Bias

All reports in this study received a positive (+) rating for quality, validity, and rigor according to the Academy of Nutrition and Dietetics Quality Criteria Checklist (20). All the studies used in this review were randomized control trials with strong study design, execution, and appropriate statistical analysis which lend a high level of credibility to their findings. The samples used and the results found in these studies reflect real world scenarios and depict the populations of interest in this review, the general adult population of developed countries, especially including the USA.

Strengths & Limitations of the Review

Strengths of this study include the use of standardized outcome measures (blood cholesterol levels), which provide a consistent baseline from which to compare results. Another strength is the rigorous systematic design of this review, including clear guidelines of the process by which results were obtained. Additionally, all studies used in this review were randomized control trials, the most rigorous research design available for comparing the efficacy of an intervention

There were some limitations to this review. One limitation, which reoccurred in several studies was that intervention foods were often eaten in combination with participants' normal diets. Without further identification of the impact of other foods in their diets, results drawn from these groups may be affected by the presence of other food factors which were not completely accounted for. Another limitation is all studies used in this review were conducted for relatively brief time frames ranging from a few weeks to a few months. These may not be accurate timeframes from which to draw long term health implications for the effect diet has on blood lipoproteins and lipid classes. Another limitation of this review included the differences in serving sizes for intervention foods, which may impact dose of fat content, and thus the postprandial cholesterol response of participants. Finally, when considering the impact of various nutrients in whole food nutrition interventions, it is important to consider the whole food matrix of these nutrients and how they interact synergistically. The results of these studies were no exception.

Application for Practitioners

According to the research in this review, minimally processed lean red meats and full fat dairy products have not been demonstrated to cause negative impacts on blood cholesterol levels when consumed in the context of an overall healthy diet pattern. A notable exception to this is the effect of butter on LDL-C and TC. Accordingly, practitioners may advise patients on the impact of other nutrients in red meats, and how consuming lean cuts of red meats can meet these needs without excessive restriction of cultural foods. In relation to full fat dairy products, it is important to consider that 90% of USA citizens do not consume the recommended three servings of dairy products daily (15,75). Based on the findings of this review and the current daily intake of dairy products in the USA, practitioners may advise patients to consume full and regular fat dairy products, such as cheese and yogurt, where they enjoy in order to encourage intake of the recommended daily servings of minimally processed dairy foods (5,8,15, 25,34,63,67,68,76). Overall, practitioners can advocate for the consumption of low sugar dairy products of multiple kinds, without saturated fat content being the focus of selection. This difference in recommendations can allow for the crucial factor of taste to be incorporated more thoroughly into patients' diets, while maintaining a holistic perspective on the impact of these foods on physical as well as mental health (75).

5 | CONCLUSION

In conclusion this review sheds light on the relationship between red meat and high-fat dairy, particularly butter, intake on CVDs and blood cholesterol levels of LDL-C, HDL-C, TC, and TG. The findings of this review highlight the complexity of understanding the effects of diet on cardiovascular health, disease, and risk. Currently, there is some evidence which supports lean red meat does not have a negative impact on cardiovascular health apart from overall elevated SFA content. Future research is warranted using standardized measures for portion sizes of meat products, fat content terminology, and more in-depth analysis of lipidomics post consumption of minimally processed red meat products to confirm this effect. The research in this review regarding butter intake primarily agrees with current recommendations for butter consumption as well as the role of butter consumption on total LDL-C concentration and cardiovascular health. In relation to other dairy products, future research is warranted using standardized measures for portion sizes of dairy products, fat content terminology, and more in-depth analysis of lipidomics post consumption of a larger array of minimally processed full fat dairy products, including yogurt, kefir, ghee, cottage cheeses, and many different types of commonly consumed cheeses.

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Authorship

DF and KH were responsible for the study design and revising. DF was responsible for data collection. DF drafted the manuscript, and KH revised the various drafts. All authors read and approved the final manuscript.

7 | CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

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