

What is the effect of saturated fat intake on increased risk of cardiovascular disease or type 2 diabetes?

Conclusion

Strong evidence indicates that dietary saturated fatty acids (SFA) are positively associated with intermediate markers and end-point health outcomes for two distinct metabolic pathways: 1) increased serum total cholesterol (TC) and LDL cholesterol (LDL-C) and increased risk of cardiovascular disease (CVD) and 2) increased markers of insulin resistance and increased risk of type 2 diabetes (T2D). Conversely, decreased SFA intake improves measures of both CVD and T2D risk. The evidence shows that a five percent energy decrease in SFA, replaced by monounsaturated fatty acids (MUFA) or polyunsaturated fatty acids (PUFA), decreases risk of CVD and T2D in healthy adults and improves insulin responsiveness in insulin resistant and T2D subjects.

Grade: Strong

Overall strength of the available supporting evidence: Strong; Moderate; Limited; Expert Opinion Only; Grade not assignable For additional information regarding how to interpret grades, [click here](#).

Executive Summary Overview

The Nutrition Evidence Library (NEL) review of the literature published since 2004 on the association of dietary saturated fat (SFA) and cardiovascular disease (CVD) identified 12 studies in healthy adults or those at elevated chronic disease risk. Studies were conducted in the US, Europe and South America, and overall, 10 randomized controlled trials (RCTs), one non-randomized trial and an analysis of 11 pooled cohorts with meta-analysis were identified. The intervention studies ranged in sample size from 14 to 191 subjects and the pooled analysis included 344,696 subjects. Of the 12 studies, eight were methodologically strong (Azadbakht, 2007; Berglund, 2007; Chen, 2009; Furtado, 2008; Jakobsen, 2009; Kralova, 2008; Lefevre, 2005; Lichtenstein, 2005) and four were methodologically neutral (Buenacorso, 2007; Bourque, 2007; Chung, 2004; Dabadie, 2005).

Most methodologically strong studies were feeding trials with an "average American" diet at baseline, which involved a reduction in SFA through replacement with monounsaturated fat (MUFA), polyunsaturated fat (PUFA) or, to a lesser extent, carbohydrates (CHO). Dietary SFA replacement (5% to 7% of energy) with either MUFA (Berglund, 2007; Lichtenstein, 2005) or PUFA (Chung, 2004; Kralova, 2008; Lichtenstein, 2005) significantly decreased total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C). Replacement of SFA with CHO decreased plasma total and LDL-C. However, compared to MUFA or PUFA, CHO decreased high-density lipoprotein (HDL-C) and increased serum triglycerides (TG) (Berglund, 2007). A study by Lefevre et al (2005) included two levels of total fat (30% and 25%) and SFA (9% and 6%) in the Step I and Step II diets, respectively, and demonstrated a dose-response effect in lowering LDL-C. However, compared to the average American diet, the Step I and Step II diets also decreased HDL-C and raised TG levels in the blood. Furthermore, these authors showed that subjects who were insulin resistant responded less favorably to the Step II diet than did those with normal insulin sensitivity. A study by Kralova et al (2008) examined changes in cholesterol efflux to determine whether reduced HDL-C, on a high PUFA/low SFA diet, had a negative effect on reverse cholesterol transport. The study showed no change in cholesterol efflux.

One meta-analysis examined effects of SFA reduction on incident coronary heart disease (CHD) outcomes by estimating the anticipated effects from statistical models where SFA is exchanged for equal energy from MUFA, PUFA or CHO (Jakobsen, 2009). These authors examined 11 American and European cohort studies and found a significant inverse association for PUFA (with 5% substitution for SFA) and coronary events (hazard ratio (HR) = 0.87, 95% CI: 0.77 to 0.97, and coronary death HR = 0.74, 95% CI: 0.61 to 0.89). They also found a positive association between substitution of MUFA or CHO for SFA and risk of coronary events, but not risk of coronary deaths.

The NEL systematic review of the literature published since 2000 on the association of dietary SFA and type 2 diabetes (T2D) identified 12 studies conducted in the US, Europe, Canada and China that examined the effect of dietary SFA on altered glucose metabolism, markers of insulin resistance and T2D risk. Two were methodologically strong review articles, including one that evaluated 15 trials, nine trials in 358 non-diabetic subjects and six trials in 93 subjects with T2D (Galgani, 2008) and one reviewing 14 prospective cohort and five cross-sectional studies (Hu, 2001). Nine were RCTs ranging in size from 11 to 522 subjects, including six methodologically strong studies (Han, 2001; Lindstrom, 2006a; Lindstrom, 2006b; Lopez, 2008; Perez-Jimenez, 2001; Vesby, 2001) and three methodologically neutral studies (Paniagua, 2007; Shah, 2007; St-Onge, 2003). The one prospective cohort study with 84,204 subjects from the Nurses' Health Study was methodologically strong (Salmeron, 2001).

Evidence Summary Paragraphs

Cardiovascular Disease (CVD)

Azadbakht et al, 2007 (positive) This was an RCT conducted in Tehran, Iran to determine the effects of the National Cholesterol Education Program (NCEP) Step II diet on LDL-C and HDL-C particle size in dyslipidemic adolescents. 46 subjects (23 female, 23 male, mean age 14.5 years, range 10 to 18 years) with hypercholesterolemia (TC more than 170mg per dL; LDL-C higher than 110mg per dL) were recruited from among the participants in the Tehran Lipid and Glucose Study and randomized to either the control group (instructed to "eat as usual") or the Step II diet intervention group. Subjects in the Step II group were given individualized diets based on energy needs that were 30% total fat, less than 7% SFA, less than 200mg cholesterol, less than 15% of energy as MUFA and less than 10% of energy as PUFA. Subjects were visited every two weeks (three-day diet record) and were in daily contact with a nutritionist. Forty-four subjects completed the trial, and there were no significant (NS) changes in body weight or physical activity in the two groups. Lipoprotein particle size was the major outcome variable, measured at three months. Comparisons were made by repeated measurement analysis of variance (ANOVA). The Step II diet resulted in a greater reduction in TC (-13±4 vs. -2±3mg per dL, P<0.001) and LDL-C (-9±2 vs. 3±0.6mg per dL, P<0.01) and a higher increase in the size of the LDL particle (1.7±0.4 vs. 0.1±0.4nm, P<0.001). High-density lipoprotein cholesterol particle size did not change significantly.

Berglund et al, 2007 (positive quality) This was a randomized crossover trial conducted in the US that compared MUFA with CHO as a replacement for SFA in subjects with a high metabolic risk profile. Fifty-two men and 33 women, selected to have any combination of HDL-C 30th percentile, triacylglycerol (TG) 70th percentile or insulin 70th percentile, were enrolled. Four research centers each enrolled participants between ages 21 and 65 years. The subjects consumed an average American diet (AAD; 36% of energy from fat) and two additional diets in which 7% of energy from SFA was replaced with either CHO (CHO diet) or MUFA (MUFA diet). (It should be noted that the CHO diet also contained more fiber than the AAD). The three diets were fed in a double-blind, three-way crossover with each diet lasting seven weeks with a washout

period of four to six weeks. All food was provided (following NCEP Step 1 guidelines). Blood samples were drawn at weeks five, six and seven of each of the three diets. Initially, 110 subjects were enrolled in the study, but only 85 completed all three diets (33 females, 52 males, mean age 35.5±9.2 years, range 21 to 61 years). Relative to the AAD, LDL-C was lower with both the CHO-replacement diet (-7.0%) and MUFA-replacement diet (-6.3%) with NS difference between the latter two diets, whereas the difference in HDL-C was significantly smaller (P<0.01) during the MUFA-replacement diet (-4.3%) than during the CHO-replacement diet (-7.2%). In addition, whereas plasma TG concentrations tended to be lower with the MUFA diet than with the AAD (-4.9%; P<0.03), TG concentrations were significantly higher with the CHO diet than with either the AAD (6.5%) or the MUFA (11.4%) diet (P<0.01 for each comparison). Lipoprotein (a) concentrations increased with both the CHO-replacement diet (20%) and MUFA-replacement diet (11%) relative to the AAD, although the difference between MUFA and CHO was not statistically significant. The authors conclude that in the study population who were at increased risk of CHD, MUFA replacement of SFA provided a greater protective effect than CHO replacement of SFA in the diet.

Buonacorso et al, 2007 (neutral quality) This was an RCT conducted in Brazil that examined the effects on HDL2 and HDL3 composition and rates of cell cholesterol efflux (CE) from macrophages induced by whole plasma and HDL-C subfractions. The RCT compared trans fatty acids (TFA), SFA and PUFA-enriched diets in healthy subjects under fasting and post-prandial conditions. After a two-week run-in period where subjects consumed diets that met the NCEP-ATPIII recommendations (30% energy from fat, less than 10% energy SFA, less than 300mg cholesterol per day), 30 healthy subjects (nine male, 21 female, matched for age, sex and body mass index (BMI) were assigned to a four-week experimental diet period composed of fat-free ad lib breakfast plus prepared frozen lunches and dinners. All experimental diets had 30% of energy as fat, and the composition of the custom-made fat was two thirds of total fat intake. The oil composition was calculated to provide minimal variation in MUFA and maximal differences in the proportions of TFA, PUFA, and SFA in the experimental diets [8.3% TFA (N=10), 14.6% PUFA (N=10) or 13.2% SFA (N=10)]. Plasma TC and triacylglycerol levels were NS changed by the diets, by time (basal vs. final test), or period (fasting vs. post-prandial) according to repeated-measures analysis. However, there were modest, but significant, differences in the chemical composition of HDL subfractions, primarily in HDL2 (the largest, least-dense HDL). Trans fatty acids increased HDL2-C, apoAI and AII, and decreased the ratio of lipids:apoA, whereas SFA decreased HDL2-C and apoAI and AII; PUFA decreased only lipids:apoA over time. Total HDL-C changes were similar to those for HDL2. However, despite the modifications in HDL2 and total HDL with diets, the percentage of radioactive cholesterol efflux from macrophages did not change, possibly due to the modest difference in the composition of the HDL fraction under conditions of maintaining 30% energy as fat.

Bourque et al, 2007 (neutral quality) This was a randomized, single-blind, crossover study to examine whether consumption of medium-chain triglycerides (MCT) with phytosterols and n-3 PUFA improves serum lipid profiles. The study evaluated the effect of a functional oil (FctO) with MCT as 50% of fat, phytosterols (22mg per kg body weight) and n-3 FA as 5% of fat, compared with beef tallow-based diet (BT) as control (treatment fat completely beef tallow), on circulating lipids and aminothiol concentrations. In this partially in-patient trial, 17 overweight women (mean age 44±4 years, BMI=32kg/m²) consumed each oil as part of an energy controlled diet [three isocaloric meals a day [45% CHO; 15% protein (PRO); 40% FAT] with 75% fat as treatment fat] for 27 days, with a four-week washout between phases. Meals were consumed at the Clinical Nutrition Research Unit (CNRU) at McGill University. Fasting blood samples were taken at days one, 26 and 28. Mean plasma TC was 9.1% lower on FctO (4.37±0.20mmol per L) vs. BT (4.80±0.20mmol per L) (P<0.0001). Mean plasma LDL-C was also lower following FctO (2.39±0.15mmol per L) vs. BT (2.86±0.16mmol per L) (P<0.0001), representing a 16% difference between diets. High-density lipoprotein cholesterol and circulating TG remained unaffected by treatment. Ratios of HDL:LDL and HDL:TC were higher by 22% and 11% (P<0.01), respectively, on FctO vs. BT. The authors conclude that consumption of a functional oil composed of MCT, phytosterols and n-3 fatty acids for 27 days improved the cardiovascular risk profile of overweight women.

Chen et al, 2009 (positive quality) This was a randomized, double-blind cross-over study to determine the effect of three daily servings of plant sterol (PS), in the context of two background diets on serum lipids, lipoproteins, retinol, tocopherols and carotenoids. Overall, there were four diets as follows: 1) Typical American Diet (TAD) with and without 3.8 g per day PS, and 2) the Step I diet with and without 3.8 g per day PS. This was a cross-over design with 23 days per diet period and no washout between diets. All foods were provided by the Beltsville Human Nutrition Research Center at US Department of Agriculture (USDA). Measurements were taken at baseline and day 22 and 24. Significant differences were measured in plasma TC, HDL-C, LDL-C, Apo A1 and Apo B; these were 4.3%, 5.3%, 4.5%, 2.8% and 2.5% lower, respectively, with the Step I diet vs. TAD. Diet had no effect on the TC/HDL-C ratio. Plant sterol intake significantly lowered TC, LDL-C and Apo B by 9.0%, 12.4% and 6.1% and the TC/HDL-C ratio by 9.6%, respectively. However, HDL-C and Apo A1 were not affected by PS. The authors concluded that the PS effect in lowering plasma TC and LDL-C was independent of, and additive to, the effect of dietary fat reduction with the Step I diet. Plasma levels of the retinoids, carotenoids and tocopherols measured were significantly decreased with PS intake, except for retinol and d-tocopherol. This was the first study to compare the influence of diets vs. PS intake on blood lipoprotein concentrations. The findings confirm that LDL-C-reducing effects resulting from PS intake and from the Step I diet are independent of each other and that the PS effect is quantitatively greater.

Chung et al, 2004 (neutral quality) This was a randomized crossover trial conducted in the US that examined the acute and chronic effects of consuming a PUFA- or SFA-rich diet on lipoprotein cholesterol levels and the impact of post-prandial TG-rich lipoproteins (TRLs) in determining lipoprotein cholesterol levels. The effects of PUFA-rich [ratio of PUFAs to SFAs (P:S) = 2.0] and SFA-rich (P:S=0.25) diets on fasting and post-prandial plasma lipid and lipoprotein-cholesterol concentrations was conducted with 16 normolipidemic subjects. Eight men (seven white and one black) aged 33 to 49 years (35.3±4.5 years) and eight post-menopausal women (five white and three black) aged 45 to 62 years (51.9±6.6 years) were recruited from the General Clinical Research Center (GCRC) of the University of Alabama at Birmingham Medical Center. The mean BMI (kg/m²) of men and women were 25.3±4.1 and 29.6±4.5, respectively. The subjects adopted each diet for a 20-day period, with three- to four-week washout. Meals were prepared by the GCRC and contained 15% energy as PRO, 50% energy as CHO, 35% energy as fat and 175mg cholesterol per 1,000kcal. The SFA-rich diet provided 18.8% SFA, 11.5% MUFA and 4.7% PUFA, while the PUFA-rich diet provided 7.5% SFA, 12% MUFA and 15.5% PUFA. Fasting TC decreased significantly (-8%, P<0.05) after the PUFA-rich diet due to a decrease in LDL-C (-12.3%, P<0.05) and HDL-C (-3.8%, NS) but did not change after a SFA-rich diet. The appearance of post-prandial TRLs in plasma at four hours was linked to a significant lowering of both LDL-C (-7.4%) and HDL-C (-4.8%) after a PUFA-rich diet, but not after the SFA-rich diet. At seven hours, LDL-C and HDL-C returned to near fasting concentrations without post-prandial TRL accumulation after a PUFA-rich diet but with significant post-prandial TRL accumulation after an SFA-rich diet. Thus, in vivo post-prandial clearance of cholesterol in LDL+HDL was greater after a PUFA-rich diet than after an SFA-rich diet. The appearance of post-prandial TRLs in plasma increased the cholesteryl ester transfer protein (CETP)-mediated transfer of cholesteryl ester from LDL+HDL to TRLs in vitro. The authors conclude that dietary fat-mediated alterations in the rate of hepatic removal of post-prandial TRLs, which carry cholesterol accepted from LDL+HDL via CETP in vivo, may contribute to the dietary fat-mediated change in lipoprotein cholesterol.

Dabadie et al, 2005 (neutral quality) This was a non-randomized clinical trial, comparing the effects of two moderate intakes of myristic acid on plasma lipids in 25 male members of a Benedictine monastery in the Southwest of France (mean age 61 years, range 35 to 88 years). Two different test diets were given for five weeks, separated by a four-week washout with subjects' usual diet. Both intervention diets provided approximately 2,200 kcal and 15% energy as PRO, 12% from oleic acid, 6% from linoleic acid (LA), 1% from alpha-linolenic acid (ALA) and 200mg cholesterol per day. In diet one, 30% of the calories came from fat (8% SFA, 0.6% myristic acid) (PUFA:SFA =1), while in diet two, 34% of the calories came from fat (11% SFA, 1.2% myristic acid) (PUFA:SFA=0.75). In comparison with baseline (fat and SFA intakes of 34.5% and 13%, respectively), both diets decreased TC, LDL-C and TG (P<0.001); HDL-C was not modified and the apo A-I/apo B ratio was increased (P<0.001).

Plasma TG were lower after diet two than after diet one, whereas, HDL-C was higher ($P < 0.05$). This was unexpected as diet one closely resembles the Step II diet, whereas diet two more closely resembles the Step I diet, except for the differences in myristic acid. Both diets were associated with an increase in ALA in cholesteryl esters ($P < 0.05$), but only diet two was associated with an increase in docosahexaenoic acid (DHA) in cholesteryl esters ($P < 0.05$). The authors conclude that moderate intake of myristic acid (1.2% of total calories) has beneficial effects on serum lipids and increases DHA content of cholesterol esters, due to increased elongation and desaturation of ALA.

Furtado et al, 2008 (positive quality) This was a randomized crossover trial that examined the differences in apo B-containing lipoproteins with and without apo C-III after three healthy diets based on the Dietary Approaches to Stop Hypertension (DASH) trial diet. Apo B-containing lipoproteins with apo C-III have slower clearance from plasma and the concentration of apo C-III in very-low density lipoprotein (VLDL) cholesterol and LDL-C is a newly emerged, predictive indicator of CHD. Study diets were modeled on the DASH diet and emphasized CHO, unsaturated fatty acids or protein. Subjects were participants in the Omni-Heart trial and each participant was randomly assigned each of three diets for six weeks, with a two-week washout in between. The three diets differed as follows: 1) Carb diet [58% of energy from CHO, 27% fat (6% SFA, 13% MUFA, 8% PUFA) and 15% PRO (5.5% meat, 9.5% plant and dairy)]; 2) Unsat diet [48% of energy from CHO, 37% fat (6% SFA, 21% MUFA, 10% PUFA) and 15% PRO (5.5% meat, 9.5% plant and dairy)] and 3) Prot diet [48% of energy from CHO, 27% fat (6% SFA, 13% MUFA, 8% PUFA) and 25% protein (9% meat, 15% plant and dairy)]. One hundred ninety-one adult men and women from Boston, MA and Baltimore, MD (44% women, mean age 53±10 years) were enrolled, 162 completed the trial. Compared with the Carb diet, the Prot diet reduced plasma apo B and triglycerides in VLDL with apo C-III (16%, $P = 0.07$; 11%, $P = 0.05$, respectively), and apo B in LDL with apo C-III (16%, $P = 0.04$). Compared with the Unsat diet, the Prot diet reduced TG in VLDL with apo C-III (16%, $P = 0.02$), and compared with baseline (subjects' usual diet was higher in SFA), the Prot diet reduced apo B in LDL with apo C-III (11%, $P = 0.05$). Compared with baseline, all three diets reduced plasma total apo B (6% to 10%, $P < 0.05$), apo B in the major type of LDL [LDL without apo C-III (8% to 10%, $P < 0.01$)], and reduced the ratio of apo C-III to apo E in VLDL. The major conclusion of the authors was that substituting PRO for CHO, in the context of a healthy diet like DASH, reduced atherogenic apo C-III-containing LDL and its precursor, apo C-III-containing VLDL, resulting in the most favorable profile of apo B lipoproteins.

Jakobsen et al, 2009 (positive quality) This was a follow-up study in which data from 11 American and European cohort studies were pooled and analyzed using the Proportional Hazards Model. The outcome measure was incident CHD. Within each study, hazard ratios (HR) with 95% CI for the incidence of CHD and mortality from CHD were calculated using the Cox proportional hazards regression with time in study (y) as the time metric. The purpose of this pooled analysis was to investigate the associations between replacing SFA intake with MUFA, PUFA or CHO and risk of CHD, while assessing the potential effect-modifying role of sex and age. The inclusion criteria for what is entitled the "Pooling Project of Cohort Studies on Diet and Coronary Disease" were the following: 1) Published follow-up studies with more than 150 incident coronary events; 2) availability of usual dietary intake; and 3) validation or repeatability study of the diet-assessment method. Exclusion criteria were based on subjects and included: 1) Age less than 35 years, 2) history of CVD, T2D or cancer, and 3) high energy intake. During four- to 10-year follow-up, 5,249 coronary events and 2,155 coronary deaths occurred among 344,696 persons. Overall, Jakobsen found a significant inverse association between 5% substitution of PUFAs for SFAs and risk of coronary events (HR: 0.87; 95% CI: 0.77, 0.97) and risks of coronary deaths (HR: 0.74; 95% CI: 0.61, 0.89). There was indication of a positive association between substitution of MUFAs and risk of coronary events (HR: 1.19; 95% CI: 1.00, 1.42), but not risks of coronary deaths. There was also a modest, but significant, association between substitution of CHO and risk of coronary events (HR: 1.07; 95% CI: 1.01, 1.14) but not risk of coronary deaths. There was no effect modification by gender or age. The authors concluded that the associations found suggest that replacing SFA intake with PUFA intake, rather than MUFA or CHO intake, prevent CVD over a wide range of intakes among all middle-aged and older men and women. Limitations of this report were that the authors did not describe the demographics of any of the American or European subject populations and the methods of handling withdrawals was not described. It is also important to note that the type of CHO in the diet was not taken into account in this analysis (i.e., extent of processing, fiber content or glycemic index).

Kralova et al, 2008 (positive quality) This was a randomized cross-over study to determine if a decrease in HDL-C in a diet enriched with PUFA is detrimental to reverse cholesterol transport (RTC) by measuring changes in cholesterol efflux (CHE). The dietary intervention consisted of two isocaloric diets that were 40% energy from fat, one high in SFA (52% of fat; SFA diet) and one high in PUFA (41% of fat; PUFA diet). Blood samples were taken at baseline and at the end of each four-week period. Serum lipids were measured by standard methods and weight and waist circumference (WC) at baseline and at the end of each four-week period. Cholesterol efflux was measured using cells in culture in medium containing labeled cholesterol. Overall, the authors found that the PUFA diet resulted in significantly lower concentrations of TC, LDL-C and HDL-C, compared to the SFA diet. Similarly, apoB and apoA1 concentrations were lower, although not significantly so. CHE was not different on either diet and was comparable to baseline. No correlation was found between CHE and lipids and lipoprotein concentrations on either diet. In conclusion, the decrease in HDL-C resulting from replacement of SFA by PUFA in the diet does not affect the rate of CHE and does not have a detrimental effect. According to the authors, this is the first study to show that replacement of SFA by PUFA in humans does not influence CHE from macrophages to the blood.

Lefevre et al, 2005 (positive quality) This was a randomized, double-blind, three-period crossover study to examine the relationship between indices of adiposity and insulin resistance and the magnitude of lipid response in healthy men, comparing diets that were reduced in TC and SFA. This study examined the effects of three diets that differed in total fat on serum lipids: The Average American Diet (AAD), the Step I diet and the Step II diet. Free-living participants were provided prepared meals throughout the study from the Pennington Biomedical Research Center (each day, one complete meal underwent chemical analysis in Pennington's food analysis laboratory). The diet periods were six weeks and fed to healthy men aged 22 to 64 years at levels to maintain body weight. Blood samples were taken at baseline and at weeks four, five and six. Step I and II diets lowered LDL-C by 6.8% and 11.7%, HDL-C by 7.5% and 11.2%, and raised TG by 14.3% and 16.2%, respectively, compared to the AAD. There was a significant positive correlation between the Step II diet and changes in LDL-C, ratio of TC to HDL-C and baseline percentage body fat, BMI and insulin. Subdivision of the subjects based on fasting insulin levels showed that people in the upper one-half of fasting insulin concentrations averaged only 57% of the reduction in LDL-C of subjects in the lower half, with the Step II diet. The authors conclude that people who are insulin resistant respond less favorably to the Step II diet than do those with normal insulin sensitivity.

Lichtenstein et al, 2006 (positive quality) This was an RCT to assess the efficacy of soybean oils (SO) with modified fatty acid profiles, compared to soybean and partially hydrogenated SO, on CVD risk in middle-aged and older moderately hyper-cholesterolemic and postmenopausal women and men. Subjects were randomly assigned to five experimental diets for a 35-day period. Subjects ate one meal per day on site and the remaining meals were provided in containers. Diets were designed to provide 30% energy from fat and two-thirds of fat was provided by experimental oils. Experimental oils were provided by Solea Co (St Louis, MO) as follows: 1) SO, 2) low SFA SO, 3) high oleic acid SO, 4) low ALA SO, and 5) commercially available partially hydrogenated SO. Analysis of variance with main effect of diet and subject as repeated measure was carried out for each outcome. This was followed by Tukey's significant difference type of adjustment for the pairwise comparison among each of the five treatment protocols. Both plasma fatty acid (FA) profiles and lipids and lipoproteins were assessed by standard methods. Fasting (12 hours) blood samples were taken three times after day 28 of the diet feeding period. The authors found that the phospholipids fraction of plasma reflected the predominate fat in the diet at the end of each study and was evidence of dietary compliance. Low-density lipoprotein cholesterol concentrations were highest in subjects who consumed the Hydrog-SO enriched diets. The effects of modified SOs were modest. Relative to the SO diet, the percentage of difference in LDL-C concentrations were: -3.2% for LoSFA-SO diet; 1.4% for HiOleic-SO diet;

0.8% for LoALA-SO diet; and 5.6% for the Hydrog-SO diet. This pattern of difference was reflected in the Apo B concentrations. High-density lipoprotein cholesterol concentrations were not different across modified SO diets, although for men, HDL-C concentrations on the HiOleic-SO diet were significantly greater than with the SO diet. Apo A1 concentrations were consistent with the HDL-C levels. The TC/HDL-C ratio was highest for the Hydrog-SO diet. No significant effect was observed on VLDL, triacylglycerol, Lp[a] or C-reactive protein (CRP) in the different SO-enriched diets. Overall, all of the unhydrogenated SOs resulted in a more favorable lipoprotein profile than Hydrog-SO.

Type 2 Diabetes

Galgani et al, 2008 (positive quality) This was a systematic review to analyze the effect of specific dietary fatty acids on insulin sensitivity and modification of T2D incidence in humans. The authors conducted a literature search in PubMed for randomized clinical trials on human subjects published up to August 2007. As background, descriptive epidemiological studies reported that dietary SFA is directly, and unsaturated fat is inversely, associated with incidence of T2D or impaired insulin sensitivity. This review focused on controlled intervention studies. Forty-one studies were identified in the search, but only 15 trials met the authors' quality criteria that included well-powered studies, evidence of dietary compliance, body weight stability and glucose disposal rate corrected for hepatic glucose production. According to these criteria, the authors included nine trials in non-diabetic subjects (N=358) and six trials in subjects with T2D (N=93). Three studies reported a differential effect on insulin sensitivity, showing decreased insulin sensitivity after SFA diets vs. MUFA or PUFA diets, yet increased insulin resistance was observed after fish oil supplementation in T2D individuals. Of these three studies, the best rated study was by Vesby et al (2001) who reported a significant decrease in insulin sensitivity of 10% after consuming a SFA diet for 12 weeks; whereas, there was no decrease in insulin sensitivity observed with MUFA diet. Twelve of fifteen studies found no effect relating to fat acid type on insulin sensitivity; however, these studies had multiple methodological and design flaws. In contrast, the high-quality Vesby et al study found that SFA diet decreased insulin sensitivity in comparison to a high MUFA diet. Overall, the authors conclude that the role of dietary fatty acids on insulin sensitivity in human subjects should be further studied.

Han et al, 2007 (positive quality) This was an RCT conducted in a group of 40 free-living subjects in an urban area of China. The trial tested if MCT intake has beneficial effects on body weight, insulin sensitivity and serum lipid profiles when administered at moderate dose to overweight T2D subjects. Subjects were randomized to consume 18g per day of either MCT oil or long chain TG (LCT)-rich corn oil administered as part of daily food intake for a 90-day test period. No additional dietary restrictions were recommended. Forty subjects completed the trial (eight males and 32 females, aged 45 to 65 years). The MCT group demonstrated an across-time reduction in body weight and WC, an increase in serum C-peptide concentration, a reduction in homeostasis model assessment of insulin resistance (HOMA-IR) and a decrease in serum cholesterol concentration ($P<0.05$, repeated measures) and between groups, while there were no differences in these parameters in the LCT group. These changes in the MCT group were also associated with an involuntary reduction in energy intake in the MCT group ($P<0.05$, repeated measures). The results suggest a link between moderate consumption of MCT and improved risk factors in moderately overweight T2D subjects.

Lindstrom, Ilanne-Parikka et al, 2006 (positive quality) The Finnish Diabetes Prevention Study (DPS) RCT assessed long-term results of the lifestyle intervention originally aimed at reducing risk for developing T2D in high-risk individuals. Overweight (mean BMI=31.1) middle-aged men (N=172) and women (N=350) with impaired glucose tolerance (IGT) were randomly assigned to a lifestyle intervention or control group. After a median of four years of active intervention, participants who were still free of diabetes were followed up for a median of three years, with median total follow-up of seven years. Diabetes incidence, body weight, physical activity and dietary intakes of fat, SFA and fiber were measured. Subjects in the intervention group were provided with intensive diet-exercise counseling with goals of: Weight reduction more than 5%, less than 30% energy from fat, less than 10% energy from SFA, fiber intake more than 15g per 1,000kcal and 30-minute moderate activity per day. The duration of the intervention ranged from less than one year to six years, with a median length of four years. There were 190 subjects in the intervention group and 165 subjects in the control group at the first post-intervention follow-up visit. During the seven-year follow-up, 75 subjects in the intervention group and 110 in the control group were diagnosed with T2D; the incidence of T2D was 4.3 per 100 person-years in the intervention group and 7.4 per 100 person-years in the control group ($P=0.0001$), indicating a 43% reduction in relative risk (RR). Beneficial lifestyle changes were maintained after the discontinuation of the intervention, and the corresponding incidence rates during the post-intervention follow-up were 4.6 per 100 person-years in the intervention group and 7.2 per 100 person-years in the control group ($P=0.0401$), indicating 36% reduction in RR.

Lindstrom, Peltonen et al, 2006 (positive quality) This was an RCT to examine the association of macronutrient composition and energy density on body weight, WC and T2D incidence in the Finnish Diabetes Prevention Study (DPS). Overweight (mean BMI=31.1kg/m²), middle-aged men (N=172) and women (N=350) with IGT were randomized to receive either 'standard care' (control) or intensive dietary and exercise counseling. Baseline and annual examinations included assessment of dietary intake with three-day food records and diabetes status by repeated 75g OGTTs. For these analyses, the treatment groups were combined and only subjects with follow-up data (N=500) were included. Originally, 522 men and women (mean age 55 years) were randomized to either the intervention (N=265, 66% women) or the control group (N=257, 69% women); after exclusion for missing dietary data or lack of follow-up, 500 subjects remained. Subjects in the control group were given general verbal and written health behavior information at baseline without specific individualized advice. Subjects in the intervention group were provided with intensive diet-exercise counseling with goals of: Weight reduction more than 5%, less than 30% energy from fat, less than 10% energy from SFA, fiber intake more than 15g per 1,000kcal, and 30-minute moderate activity per day. The duration of the intervention ranged from less than one year to six years, with a median length of four years. After a mean follow-up of 4.1 years, 114 out of 500 of the participants had been diagnosed with T2D. Comparing the highest to the lowest quartile, hazard ratios (HR) for T2D incidence were 0.38 (95% CI: 0.19 to 0.77) for fiber intake, 2.14 (95% CI: 1.16 to 3.92) for fat intake and 1.73 (95% CI: 0.89 to 3.38) for SFA intake, after adjustment for confounding variables. The authors conclude that dietary fat and fiber intake are significant predictors of sustained weight reduction and progression to T2D in high-risk subjects, even after adjustment for other risk factors.

Lopez et al, 2008 (positive quality) This was a randomized, single-blinded, within-subject crossover controlled trial of 14 healthy men in Spain to determine the degree to which unsaturation of dietary fatty acids influences the postprandial control of insulin secretion and insulin sensitivity. The post-prandial response to high-fat meals enriched in SFAs or MUFAs was assessed using mixed meals with common foods. The isocaloric diet interventions included 9% more fat, replacing carbohydrate in the control NCEP diet, and were as follows: 1) NCEP Step 1, 2) high butter (MUFA:SFA, 0.48:1.0), 3) refined olive oil (ROO) (MUFA:SFA, 5.43:1.0), 4) high palmitic sunflower oil (HPSO) (MUFA:SFA, 2.42:1.0), and 5) mixture of vegetable and fish oils (VEFO) (MUFA:SFA, 7.08:1.0). Subjects were normo-triglyceridemic and had normal fasting blood glucose and glucose tolerance. Results showed that high-fat meals increased the post-prandial concentrations of insulin, TG and FFAs, and they increased post-prandial b-cell activity as assessed by the insulinogenic index (IGI), a surrogate measure of first-phase insulin secretion; IGI/HOMA-IR ratio; AUC insulin/glucose ratio; and HOMA of b-cell function (HOMA-B). High-fat meals also decreased post-prandial insulin sensitivity assessed by a glucose and TG tolerance test meal (GTTM)-determined insulin sensitivity test and the post-prandial Belfiore indices for glycemia and blood FFAs. These effects were significantly improved, in a linear relationship, when MUFAs were substituted for SFAs; subjects became less insulin resistant post-prandially as the proportion of MUFAs, compared with SFAs, in dietary fats increased (VEFO>ROO>HPSO>butter). When the early post-prandial insulin response was used as a measure of b-cell activity, it decreased as the ratio of MUFA/SFA increased. Overall, the findings suggest that b-cell function and insulin sensitivity progressively improve in the post-prandial state as the proportion of MUFAs, relative to SFAs, increases in the diet, suggesting that MUFAs moderate the post-prandial hyperactivity of the pancreatic b-cell. The underlying mechanism

likely involves different insulinotropic potentials of individual FFA (e.g., oleic acid has been reported to elicit half the insulin secretion from b-cells as palmitic or stearic acids).

Paniagua et al, 2007 (neutral quality) This was a randomized crossover study on offspring of obese, T2D patients recruited from diabetic patients' records at primary care centers in Cordoba Spain. 59 potential subjects were recruited, but 27 subjects either did not meet the inclusion criteria or refused to participate. Qualifying subjects underwent an OGTT, after which 11 insulin resistant (IR) subjects (four men, seven women) were included in the study. Subjects had a BMI=25kg/m². Subjects were randomly assigned to three groups and underwent three diet periods of 28 days in a crossover design: 1) Diet high in SFA (SAT) increased 15% energy as SFA, 2) diet high in MUFA (MUFA) increased 15% energy as MUFA, and 3) diet high in CHO increased 18% energy as carbohydrate. Body weight and resting energy expenditure (REE) were not changed over any of the diet interventions. Fasting serum glucose decreased during the MUFA and CHO diet periods compared with SAT diet (5.02±0.1, 5.03±0.1, 5.50±0.2 mmol per L, respectively. ANOVA was less than 0.05). The MUFA diet improved insulin sensitivity indicated by lower HOMA-IR, compared to CHO and SAT diets (2.32±0.3, 2.52±0.4, 2.72±0.4, respectively, ANOVA was less than 0.01). Compared to a CHO breakfast, the AUC of post-prandial glucose and insulin were lower with MUFA or SAT breakfasts (11.9±2.7, 7.8±1.3, 5.84±1.2 mmol x 180 minutes per L, ANOVA less than 0.05; and 2,667±329, 1,004±147, 1,253±140, pmol x 180 minutes per L, ANOVA was less than 0.01, respectively). Integrated glucagon-like peptide-1 increased with MUFA and SAT breakfasts compared with isocaloric CHO breakfast. Fasting and post-prandial HDL-C increased with MUFA diet and the AUC of TG decreased with CHO diet. Fasting pro-insulin decreased, while stimulated ratio PI/I was not changed by MUFA diet. Overall, weight maintenance with a MUFA-rich diet improves HOMA-IR and fasting proinsulin levels in IR subjects.

Pérez-Jiménez et al 2001 (positive quality) This was a randomized crossover study to investigate the effect of substitution of SFA in the diet with MUFA (Mediterranean diet) or a high-CHO diet for 28 days each. Fifty-nine normolipidemic subjects (30 men, 29 women; mean age=23.1) were recruited and completed the trial. Dietary information was collected over seven consecutive days. The initial run-in period included all subjects on a SFA-enriched diet with 38% fat (20% SFA). All participants were randomized in a crossover design with two dietary periods: High MUFA and high CHO. In comparison to the SFA diet, the CHO and MUFA diets decreased LDL-C and HDL-C. Steady state plasma glucose decreased and basal and insulin-stimulated 2-deoxy-glucose uptake increased in both diets, indicating improved insulin sensitivity. Fasting free fatty acids levels were correlated positively with plasma glucose levels.

Salmeron et al, 2001 (positive quality) This was a prospective cohort analysis of subjects from the Nurses' Health Study. Information from 98,462 respondents (women aged 34 to 59 years) whose dietary intake was assessed in 1980 was used; dietary information was assessed from a validated, semi-quantitative food-frequency questionnaire (FFQ) and updated in 1984, 1986 and 1990. After exclusion, 84,204 respondents were followed for T2D incidence from 1980 to 1994. During 14 years of follow-up, 2,507 incident cases of T2D were diagnosed. Both SFA and MUFA intakes were associated with increased RR of T2D in age and BMI adjusted analyses. This effect was greatly attenuated for SFA with multivariate analysis, including all major types of fatty acids and there was NS positive association between MUFA intake and risk of T2D after multivariate analysis. Polyunsaturated fatty acid intake, on the other hand, was inversely associated with T2D risk in all analyses. Trans fatty acid and dietary cholesterol were positively associated with risk of T2D. Using isocaloric energy substitutions, the substitution of 5% of energy from SFA with PUFA resulted in a 35% lower risk of T2D; whereas replacement of 5% SFA with CHO resulted in no change in T2D risk. Replacement of 2% energy from TFA with PUFA was associated with a 40% decreased risk of T2D.

Shah et al, 2007 (neutral quality) This was a randomized crossover trial, conducted at the General Clinical Research Center of the University of Texas Southwestern Medical Center at Dallas, which examined the effects of specific fatty acids on post-prandial TG, glucose and insulin concentrations in 11 men with T2D (mean age 54.6±12.2 years). All subjects received an isocaloric background diet containing 15% energy as PRO, 35% as fat and 50% as CHO throughout the study period. At intervals of three to four days, after an overnight fast, each subject consumed a mixed test meal for post-prandial assessment on four occasions. Each test meal provided 1,000 kcal with 15% energy as PRO, 35% as CHO and 50% as fat. The type of fat in the test meal varied on each occasion, and was rich in palmitic acid, oleic acid, LA or eicosapentaenoic acid (EPA) and DHA (made using palm oil, olive oil, safflower oil and salmon oil, respectively). According to repeated measures ANOVA, the insulin response (P=0.0002), but not the glucose response, was significantly different between meals; the insulin response was lower in meals rich in oleic acid or EPA and DHA than in meals rich in palmitic acid or LA (P<0.01). The TG response did not reach statistical significance (P=0.06), but tended to be lower with EPA and DHA than with the other fatty acids. Overall, compared to palmitic or linoleic acids, oleic acid or EPA and DHA may modestly lower the insulin response in T2D patients, without deteriorating the glucose response.

St. Onge et al, 2003 (neutral quality) This was a randomized crossover trial conducted in Canada to determine whether MCT or long chain triglyceride (LCT) consumption influences energy expenditure (EE) and substrate oxidation in overweight women. Twenty-two women (mean age 44.3±3.8 years) became inpatients at the Mary Emily Clinical Nutrition Research Unit (CNRU) of McGill University and were enrolled in two dietary phases lasting 27 days each, separated by a four- or eight-week washout period of habitual diet. All meals were provided and diets contained 40% energy as fat, 15% energy as PRO and 45% energy as CHO. During the LCT phase, 75% of fat was derived from beef tallow or a blend of SFA and unsaturated vegetable oils, while during the MCT phase, 50% of fat was provided by MCT oil, 10% by olive oil, and 5% by butter, coconut oil and flaxseed oil each. Seventeen subjects completed the trial. There were NS differences between diet phases in total and subcutaneous adipose tissue volume; however, average EE and fat oxidation were greater (P<0.05) during MCT than LCT consumption (0.95±0.019 vs. 0.90±0.024 kcal per minute, respectively, for EE and 0.080±0.0026 vs. 0.075±0.0022g per minute, respectively, for fat oxidation, respectively, both P<0.05). These results show that long-term consumption of MCT enhances EE and fat oxidation in obese women compared to LCT consumption, and MCT may, therefore, decrease weight gain due to increased EE.

Vessby et al, 2001 (positive quality) This was an RCT, conducted in five centers (Sweden, Italy, Finland, Denmark and Australia) as part of the KANWU study, that examined whether a change of dietary fat quality affects insulin sensitivity in humans. The KANWU study included 162 healthy subjects (86 males, 76 females, aged 30 to 65 years) chosen at random to receive a controlled, isocaloric diet for three months containing either a high concentration of SFA or MUFA (within the context of 37% energy as fat). Additionally, within groups, there was a second random assignment of subjects to supplements with fish oil (3.6g n-3 fatty acids per day) or olive oil placebo as capsules. The study duration was 90 days, preceded by a two-week stabilization period. Insulin sensitivity was significantly impaired in subjects on the SFA diet (-10%, P=0.03) but did not change on the MUFA diet (+2%, NS); the difference between diets was statistically significant (P=0.05). Insulin sensitivity was 12.5% lower on the SFA diet and 8.8% higher on the MUFA diet (P=0.03), but these beneficial effects were only seen at a total fat intake below median (37% of energy). Insulin secretion, however, was not affected. The addition of n-3 fatty acids did not influence insulin sensitivity or secretion. The beneficial effects of substituting a MUFA for a SFA diet on insulin sensitivity were only seen when total fat intake was below 37% of energy. Under these conditions, insulin sensitivity was 12.5% lower and 8.8% higher on the SFA diet and MUFA diets, respectively (P=0.03).

Low-density lipoprotein cholesterol increased on the SFA diet (+4.1%, P<0.01), but decreased on the MUFA diet (-5.2%, P<0.001), while lipoprotein (a) [Lp(a)] increased by 12% on the MUFA diet (P<0.001). Overall, a change in the proportion of dietary fat, replacing SFA with MUFA, improves insulin sensitivity, but has no effect on pancreatic insulin secretion. However, the beneficial effect of MUFA on insulin sensitivity is lost in individuals with high fat intake.

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Author, Year, Study Design, Class, Rating	Study Description, Duration	Study Population, Demographics	Intervention	Significant Outcomes	Limitations
<p>Azadbakht L, Mirmiran P et al, 2007</p> <p>Study Design: Randomized controlled trial</p> <p>Class: A</p> <p>Rating: </p>	<p>Three months.</p>	<p>46 dyslipidemic adolescents.</p> <p>23 female, 23 male.</p> <p>Mean age: 14.5 years (range 10 to 18 years).</p> <p>44 subjects completed study.</p>	<p>Determined effects of the NCEP Step II diet on LDL and HDL size.</p> <p>Subjects randomized to control group (instructed to "eat as usual") or the Step II diet.</p> <p>Intervention group received diets that were 30% total fat, <7% SFA, <200mg cholesterol, <15% MUFA and <10% PUFA.</p> <p>Subjects visited every two weeks and contacted by a nutritionist daily.</p> <p>Subjects completed three-day diet records every two weeks.</p>	<p>NS Δ in body weight or physical activity in either group.</p> <p>Step II diet resulted in greater ↓ in TC (-13±4 vs. -2±3mg per dL, P<0.001) and LDL-C (-9±2 vs. 3±0.6mg per dL, P<0.01) and higher ↑ in LDL particle size (1.7±0.4 vs. 0.1±0.4nm, P<0.001).</p> <p>NS Δ in HDL particle size.</p>	<p>Small sample size covering broad age range.</p> <p>Results not reported by gender.</p>
<p>Berglund L, Lefevre M et al, 2007</p> <p>Study Design: Randomized Crossover Trial</p> <p>Class: A</p> <p>Rating: </p>	<p>Three diets were fed in double-blind, three-way crossover.</p> <p>Seven-week diet period with four- to six-week washout.</p>	<p>110 subjects with high metabolic risk profile enrolled; 85 completed all three diets.</p> <p>52 men, 33 women.</p> <p>Mean age: 35.5±9.2 years (range 21 to 61 years).</p> <p>Location: United States.</p>	<p>Compared MUFA with CHO as a replacement for SFA. The three diets were average American diet (AAD), carb-replacement diet (CHO) and MUFA-replacement diet (MUFA).</p> <p>7% energy from SFA replaced with either CHO (primarily complex) or MUFA. All food was provided (following NCEP step I).</p> <p>Blood samples drawn at five, six and seven weeks of each diet.</p>	<p>LDL-C was lower with CHO (-7.0%) and MUFA (-6.3%) diets, compared to AAD.</p> <p>HDL-C) differences were less for MUFA (-4.3%) than CHO diet (-7.2%).</p> <p>Lipoprotein (a) [Lp(a)] concentration ↑ with both CHO (20%) and MUFA (11%) diets, relative to AAD.</p>	<p>Subjects body weights maintained, so dietary effects on lipid levels under "free-living" conditions were not determined.</p>
<p>Bourque C, St-Onge MP et al, 2003</p> <p>Study Design: Randomized Crossover Trial</p> <p>Class: A</p> <p>Rating: </p>	<p>27-day diet phases with eight-week washout.</p> <p>Partially inpatient trial.</p>	<p>22 overweight women enrolled; 17 completed trial.</p> <p>Mean age: 44±4 years.</p> <p>BMI: 32kg/m².</p>	<p>Compared Functional oil (FctO) with MCT as 50% of fat, phytosterols (22mg per kg BW) and n-3 FA as 5% of fat with beef tallow-based diet (BT) as control (treatment fat completely beef tallow).</p> <p>17 overweight women consumed each oil as part of an energy controlled diet [three isocaloric meals per day (45% CHO; 15% PRO; 40% FAT with 75% fat as treatment fat)] for 27 days, with four-week washout.</p> <p>Meals were consumed at</p>	<p>TC was 9.1% ↓ on FctO (4.37±0.20mmol per L) vs. BT (4.80±0.20mmol per L) (P<0.0001).</p> <p>Mean plasma LDL-C ↓ with FctO (2.39±0.15mmol per L) vs. BT (2.86±0.16mmol per L) (P<0.0001), a 16% difference between diets.</p> <p>No Δ in HDL-C and TG during both dietary phases.</p> <p>Ratios of HDL:LDL and HDL:TC ↑ by 22% and 11% (P<0.01), respectively, on FctO vs. BT.</p> <p>No Δ in plasma total homocysteine with FctO, but ↓ (P<0.05) with control, ↑ total homocysteine end points with</p>	<p>22 subjects enrolled, but only 17 completed trial; eight were postmenopausal and four were smokers.</p>

			<p>the Clinical Nutrition Research Unit (CNRU) at McGill University.</p> <p>Fasting blood samples taken at days one, 26 and 28 of each diet phase.</p>	<p>FctO (6.95±0.33mmol per L) vs. BT (6.27±0.28mmol per L) (P<0.05).</p> <p>Plasma glutathione ↑ by 0.41mmol per L with FctO.</p> <p>Consumption of a functional oil composed of MCT, phytosterols and n-3 FAs for 27 days improved the lipid profile of overweight women.</p>	
<p>Buonacorso V, Nakandakare ER et al, 2007</p> <p>Study Design: Randomized controlled trial.</p> <p>Class: A</p> <p>Rating: </p>	<p>Two-week run-in followed by four-week diet.</p>	<p>30 health subjects (nine male, 21 female, matched for age, sex and BMI).</p> <p>Location: Brazil.</p>	<p>Examined effects of TFA, SFA and PUFA enriched diets on HDL2 and HDL3 composition under fasting and postprandial conditions.</p> <p>Also examined rates of cholesterol efflux from macrophages induced by whole plasma and HDL-C subfractions.</p> <p>After a two-week run-in (30% energy=fat, less than 10%=SFA, less than 300mg cholesterol per day), subjects were assigned to a four-week experimental diet period.</p> <p>Three diets had similar [MUFA], but had either 8.3% TFA (N=10), 14.6% PUFA (N=10) or 13.2% SFA (N=10).</p>	<p>NS differences over time in plasma TC and TG concentration (repeated measures analysis).</p> <p>Modest, but significant differences in composition of HDL2, HDL3 and HDL2+HDL3.</p> <p>For HDL2: TFA diet ↑ concentrations of HDL2 TC, phospho-lipids, apoAI and apoAII; ↓ ratio of lipids:apoA over time. SFA diet ↓ TC, and apoAI and apoAII and ↑ lipids:apoA over time; the PUFA diet ↓ only lipids:apoA over time.</p> <p>HDL2 TG did not differ with diet (three-way factor interaction analysis), but ↓ over time (final P=0.041).</p> <p>Total HDL: TFA diet ↑ TC, phospholipids, apoAII and ↓ lipids:apoA; SFA diet ↓ TC, phospholipids, apoAI and apoAII.</p> <p>HDL3: When time and period were considered together, compared with SFA diet, phospholipids, apoAI and apoAII were higher and lipids:apoA was ↓ with TFA diet; apoAI and apoAII were ↑ and lipids:apoA was ↓ with PUFA diet.</p> <p>No Δ in cholesterol efflux (CHE) (% radioactive cholesterol removal) with diets.</p>	<p>Subject number small.</p> <p>Although there were significant differences in lipid and apoA composition of HDL subfractions with diet, differences were modest and may not be biologically important.</p> <p>Potential bias as recruited subjects were medical school employees.</p>
<p>Chen SC, Judd JT et al, 2009</p> <p>Study Design: Randomized Crossover Trial</p> <p>Class: A</p> <p>Rating: </p>	<p>Randomized cross-over design: 23 days per diet (no wash out).</p> <p>Mixed effects model for analysis of data for repeated measurements.</p> <p>T-test to compare mean</p>	<p>N=23 (14 men, nine women).</p> <p>Mildly hyper-cholesterolemic.</p> <p>Attrition: One.</p> <p>Mean age: 51.7±2.4 years.</p> <p>BMI: 28.0±0.6kg/m².</p> <p>No information on ethnicity or demographics.</p>	<p>Typical American Diet (TAD) designed to provide 34% energy from fat with ratio of SFA:MUFA:PUFA of 1:1:0.5.</p> <p>TAD was tested ±PS at 3.3g per day (1.8g per serving of PS as ester from vegetable oil).</p> <p>Step I diet designed to provide <30% energy from fat and <7% energy</p>	<p>TC, HDL-C, LDL-C, ApoA1 and ApoB were 4.3%, 5.3%, 4.5%, 2.8% and 2.5% lower, respectively, with Step I diet vs. TAD.</p> <p>Diet had no effect on the TC:HDL-C ratio.</p> <p>PS significantly ↓ TC, LDL-C, and ApoB by 9.0%, 12.4% and 6.1% and TC/HDL-C ratio by 9.6%, respectively.</p> <p>HDL-C and ApoA1 were not</p>	<p>Subject population was restricted to mildly hyper-cholesterolemic adults, in particular, middle-aged men and non-HRT postmenopausal women.</p> <p>No washout between diet phases.</p>

	baseline values of men and women.	Location: United States.	from SFA with ratio of SFA:MUFA:PUFA of 1:1.5:1. Step I was tested ±PS at 3.3g per day (1.8g per serving of PS as ester from vegetable oil).	affected by PS. PS effect in lowering plasma TC and LDL-C was independent of, and additive to, the effect of Step 1 diet. Plasma levels of retinoids, carotenoids and tocopherols were significantly ↓ with PS intake, except for retinol and alpha tocopherol.	
Chung BH, Cho BH et al, 2004 Study Design: Randomized crossover trial. Class: A Rating: ●	Subjects on two diets for 20 days, with three- to four-week washout.	16 healthy normo-lipidemic men and postmenopausal women. Eight men (seven white, one black), mean age: 35.3±4.5 years (range 33 to 49 years). Eight women (five white, three black), mean age: 51.9±6.6 years (range 45 to 62 years). All enrolled and completed both diet phases. Location: United States.	Subjects adopted each of two diets for 20-day period, with three- to four-week washout. Meals prepared by the research center with (%energy) 15% PRO, 50% CHO, 35% fat and 175mg cholesterol per 1,000kcal. SFA-rich diet: 18.8% SFA, 11.5% MUFA and 4.7% PUFA; PUFA:SFA=0.25. PUFA-rich diet: 7.5% SFA, 12% MUFA and 15.5% PUFA; PUFA:SFA=2.0.	TC ↓ significantly with PUFA diet due to ↓ LDL-C (-12.3%, P<0.05) and HDL-C (-3.8%, NS); no Δ after a SFA diet. Appearance of postprandial TRLs in plasma at four hours was linked to significant ↓ in LDL-C (-7.4%) and HDL-C (-4.8%) after PUFA diet; not observed after SFA diet. At seven hours, LDL-C and HDL-C returned to fasting concentrations without postprandial TRL accumulation after PUFA diet, but with significant postprandial TRL accumulation after SFA diet. The in vivo postprandial clearance of LDL-C and HDL-C was ↑ after PUFA- than SFA-rich diet. Appearance of postprandial TRLs in plasma ↑ the CETP-mediated transfer of cholesteryl esters from LDL and HDL to TRLs in vitro. Interpretation is that there is ↑ in rate of hepatic removal of post-prandial TRLs, which carry cholesterol accepted from LDL and HDL, after PUFA vs. SFA diet.	Small sample size and recruitment methods not described.
Dabadie H et al 2005 Study Design: Randomized Crossover Trial Class: A Rating: ●	Two test diets for five weeks separated by four-week washout.	25 monks at Benedictine monastery. Mean age: 61 years (range 35 to 88 years). Location: France.	Compared effects of two moderate intakes of myristic acid on plasma lipids. Both intervention diets provided 2,200kcal and 15% energy from PRO, 12% from oleic acid, 6% from LA, 1% from ALA and 200mg cholesterol per day. In diet one, 30% calories were from fat (8% SFA, 0.6% myristic acid); in diet two, 34% calories were from fat (11% SFA, 1.2% myristic acid).	Compared to baseline, both diets ↓ TC, LDL-C and TG (P<0.001). Plasma TG were ↓ after diet two than after diet one, whereas HDL-C was ↑ (P<0.05). Both diets increased alpha-linolenate of cholesteryl esters (CE) (P< 0.05). Only diet two ↑ DHA of CE (P<0.05). Overall, moderate intake of myristic acid (1.2% total kcal) has beneficial effect and ↑ DHA of CE.	Small sample size of a relatively homogenous group of men.

<p>Furtado et al 2008</p> <p>Study Design: Randomized Crossover Trial</p> <p>Class: A</p> <p>Rating: </p>	<p>Subjects on each of three diets for six weeks, two-week washout.</p>	<p>N=191 adult men and women (44% women, mean age 53±10 years) enrolled; N=162 completed the trial.</p> <p>Location: United States.</p>	<p>Examined difference in apoB lipoproteins with and without apoC-III after three healthy diets based on DASH diet.</p> <p>Subjects were randomly assigned each of three diets for six weeks.</p> <p>The three diets differed by emphasis on either CHO (Carb) [58% energy CHO, 27% fat (6% SFA, 13% MUFA, 8% PUFA) and 15% Prot (5.5% meat, 9.5% plant/dairy)].</p> <p>Unsaturated fat (Unsat) [48% of energy from CHO, 37% fat (6% SFA, 21% MUFA, 10% PUFA) and 15% Prot (5.5% meat, 9.5% plant/dairy)].</p> <p>Protein (Prot) [48% of energy from CHO, 27% fat (6% SFA, 13% MUFA, 8% PUFA) and 25% PRO (9% meat, 15% plant/dairy)].</p>	<p>Compared to Carb diet, Prot diet ↓ plasma apoB and TG in VLDL with apoC-III (16%, P=0.07; 11%, P=0.05, respectively) and apoB in LDL with apoC-III (16%, P=0.04).</p> <p>Compared with the Unsat diet, Prot diet ↓ TG in VLDL with apoC-III (16%, P=0.02) and compared with baseline, Prot diet ↓ apoB in LDL with apoC-III (11%, P=0.05).</p> <p>All three diets reduced plasma total apoB (6% to 10%, P<0.05), apoB in the major type of LDL, LDL without apoC-III (8% to 10%, P<0.01), and ↓ the ratio of apoC-III to apo E in VLDL.</p>	<p>Four-week results were similar to the six-week results, suggesting a plateau in diet effect.</p>
<p>Galgani JE et al. 2008</p> <p>Study Design: Systematic Review</p> <p>Class: M</p> <p>Rating: </p>	<p>Literature search in PubMed for RCTs published up to Aug 2007.</p>	<p>41 studies were identified; only 15 trials met the authors' quality criteria that included well-powered studies, evidence of dietary compliance, BW stability and glucose disposal rate corrected for hepatic glucose production.</p> <p>According to these criteria, the authors included nine trials in non-diabetic subjects (N=358) and six trials in subjects with T2D (N=93).</p> <p>Location: International studies.</p>	<p>Systematic review to analyze effect of specific dietary FAs on insulin sensitivity and modification of T2D incidence.</p>	<p>Three studies reported a differential effect of FA intake on insulin sensitivity, showing ↓ insulin sensitivity after SFA diets vs. MUFA or PUFA diets.</p> <p>↑ insulin resistance was observed after fish oil supplementation in T2D subjects.</p> <p>Best rated study was by Vesby et al (2001) who reported a significant 10% ↓ in insulin sensitivity after consuming a SFA diet for 12 weeks; there was no ↓ in insulin sensitivity after the MUFA diet.</p> <p>12 of 15 studies found no effect of FA type on insulin sensitivity.</p> <p>Role of dietary FAs on insulin sensitivity in human subjects should be further studied.</p>	<p>Studies that did not report an association had multiple methodological and design flaws.</p>
<p>Han JR et al 2007</p> <p>Study Design: Randomized Controlled Trial</p> <p>Class: A</p> <p>Rating: </p>	<p>90 days.</p>	<p>40 subjects enrolled and completed the trial (Eight males; 32 females).</p> <p>Age: 45 to 65 years.</p> <p>Free-living, moderately overweight T2D urban residents.</p> <p>Location: China.</p>	<p>Trial tested if MCT intake has beneficial effects on body weight, insulin sensitivity and serum lipid profile when administered at a moderate dosage to overweight T2D subjects.</p> <p>Subjects were randomized to consume</p>	<p>MCT group demonstrated a ↓ in body weight and WC, an ↑ in serum C-peptide, a ↓ in HOMA-IR and ↓ in TC over time (all P<0.05) and between groups.</p> <p>No differences in these parameters in LCT group.</p> <p>Results suggest a link between moderate consumption of</p>	<p>Homogeneous study sample.</p>

			18g per day of either MCT oil or LCT-rich corn oil for 90-day period. No additional dietary restrictions were recommended.	MCT and improved risk factors in overweight T2D subjects.	
Hu FB, Van Dam RM et al, 2001 Study Design: Meta-analysis or Systematic Review Class: M Rating: 	Medline database search from 1966 - 2000. Included cited references when relevant.	International Men and women in subpopulations in US, Europe, and Israel. Age range 25 - 89 years N = 20-4,903 subjects	14 epidemiologic studies and 5 cross-sectional studies of dietary fat and carbohydrate and association with developing hyperglycemia or type 2 diabetes	Higher intakes of polyunsaturated fatty acids (PUFA improved glucose metabolism and insulin resistance Long chain PUFA also improved glucose metabolism and insulin resistance Higher intakes of saturated fatty acids (SFA) adversely affected glucose metabolism and insulin resistance High intakes of vegetable fat and PUFA were associated with a decreased risk of type 2 diabetes	
Jakobsen MU, O'Reilly EJ et al, 2009 Study Design: Meta-analysis or Systematic Review Class: M Rating: 	Review of pooled analysis: Proportional Hazards Model.	Specific for each study.	Replacement of SFA intake with MUFA, PUFA and CHO. During four- to 10-year follow-up, 5,249 coronary events and 2,155 coronary deaths occurred among 344,696 persons (71% women).	Significant inverse association between substitution of SFA with PUFAs and risk of coronary events (HR: 0.87, 95% CI: 0.77, 0.97) and risks of coronary deaths (HR: 0.74, 95% CI: 0.61, 0.89). Association between substitution of MUFAs and risk of coronary events (HR: 1.19; 95% CI: 1.00, 1.42), but not risks of coronary deaths. Significant association between substitution of CHO and risk of coronary events (HR: 1.07; 95% CI: 1.01, 1.14), but not risks of coronary deaths. No effect modification by sex or by age.	Authors did not describe demographics of American or European populations.
Kralova Lesna I, Suchanek P et al, 2008 Study Design: Randomized Crossover Trial Class: A Rating: 	Four weeks per diet (no wash-out).	14 males; no attrition. Caucasian. Age: 18 to 55 years.	Two isocaloric diets with 40% fat: 1) SFA diet: 52% SFA, 34% MUFA, 14% PUFA 2) PUFA diet: 26% SFA, 33% MUFA, 41% PUFA.	PUFA diet significantly ↓ TC, LDL-C and HDL-C, compared to SFA diet. ApoB and apoA1 concentrations were lower, although not significantly. Cholesterol efflux CHE was not different on either diet and was comparable to baseline. No correlation between CHE and lipids and lipoprotein concentrations on either diet. ↓ in HDL-C resulting from replacement of SFA by PUFA does not affect rate of CHE.	Only generalizable to population of healthy Caucasian men; however, this is a population at risk.

<p>Lefevre M, Champagne CM et al, 2005</p> <p>Study Design: Non-Randomized Crossover Trial</p> <p>Class: C</p> <p>Rating: </p>		<p>87 men.</p> <p>Age: 22 to 64 years.</p> <p>84% white, 11% African American.</p> <p>Location: United States.</p>	<p>Three diets that differed in total fat: The Average American Diet (AAD), the Step I diet and Step II diet.</p>	<p>Step I and II diets ↓ LDL-C by 6.8% and 11.7%, HDL-C by 7.5% and 11.2% and ↑ TG by 14.3% and 16.2%, respectively, compared to AAD.</p> <p>Significant positive correlation between Step II diet and Δ in LDL-C, ratio of TC to HDL-C and baseline percentage body fat, BMI and insulin.</p> <p>Subjects in the upper one-half of fasting insulin concentrations averaged only 57% of the ↓ in LDL-C of subjects in the lower half, with the Step II diet.</p>	<p>None.</p>
<p>Lichtenstein AH, Matthan NR et al, 2006</p> <p>Study Design: Randomized Controlled Trial</p> <p>Class: A</p> <p>Rating: </p>		<p>30 subjects (16 women, 14 men).</p> <p>Mean age: 63 years.</p> <p>Ethnicity was not identified.</p> <p>Mean BMI: 26.2kg/m².</p> <p>Location: United States.</p>	<p>Subjects randomly assigned to five experimental diets for 35-day period.</p> <p>Diets provided 30% energy from fat; two-thirds of fat provided by experimental oils.</p> <p>Experimental oils: 1) SO, 2) LoSFA-SO, 3) HiOleic-SO, 4) loALA-SO, and 5) Hydrog-SO.</p> <p>Analysis of variance with main effect of diet and subject as repeated measure was carried out for each outcome.</p>	<p>LDL-C levels were highest in subjects on Hydrog-SO or loALA-SO diets.</p> <p>In men, HDL-C was significantly ↑ with HiOleic-SO.</p> <p>Ratios of LDL to apoB and HDL to apoAI were similar at end of diet phases.</p> <p>NS differences in VLDL, TG, Lp[a] or CRP in the different SO-enriched diets.</p>	<p>None.</p>
<p>Lindstrom J, Ilanne-Parikka P et al 2006</p> <p>Study Design: Randomized Controlled Trial</p> <p>Class: A</p> <p>Rating: </p>	<p>Finnish Diabetes Prevention Study.</p> <p>Duration of intervention from less than one year to six years; median, four years.</p>	<p>522 men and women.</p> <p>Mean age: 55 years.</p> <p>Randomized to intervention (N=265, 66% women) or control (N=257, 69% women).</p> <p>190 subjects in intervention group and 165 subjects in the control group at the first post-intervention follow-up visit.</p> <p>Location: Finland.</p>	<p>Intervention group provided with intensive diet-exercise counseling with goals of weight reduction of ≥5%, <30% energy from fat, <10% energy from SFA, 15g per 1,000kcal fiber and 30 minutes of moderate physical activity per day.</p>	<p>During a seven-year follow-up, 75 subjects in intervention group and 110 in control group were diagnosed with T2D.</p> <p>Incidence of T2D was 4.3 of 100 person-years in the intervention group and 7.4 of 100 person-years in the control group (P=0.0001), indicating a 43% ↓ in RR.</p> <p>Lifestyle Δ maintained after intervention stopped; T2D incidence rates for post-intervention follow-up were 4.6 of 100 person-years in the intervention group and 7.2 of 100 person-years in control (P=0.0401), indicating 36% ↓ in RR.</p>	<p>Subjects may be more health conscious than the general population.</p>

<p>Lindstrom J, Peltonen M et al 2006</p> <p>Study Design: Randomized Controlled Trial</p> <p>Class: A</p> <p>Rating: </p>	<p>Finnish Diabetes Prevention Study.</p> <p>Duration of intervention from less than one year to six years; median, four years.</p>	<p>522 men and women.</p> <p>Mean age: 55 years.</p> <p>Overweight (mean BMI: 31.1kg/m²), middle-aged men (N=172) and women (N=350) with IGT.</p> <p>Randomized to intervention (N=265, 66% women) or control (N=257, 69% women) to receive either standard care or intensive dietary and exercise counseling.</p> <p>Location: Finland.</p>	<p>Baseline and annual examinations included assessment of dietary intake with three-day food records and diabetes status by repeated 75g OGTTs.</p> <p>Intervention counseling with goals of weight reduction >5%, <30% energy from fat, <10% energy from SFA, >15g per 1,000 kcal fiber and 30 minutes of moderate activity per day.</p>	<p>After a mean follow-up of 4.1 years, 114 out of 500 of the participants had been diagnosed with T2D.</p> <p>Comparing highest to lowest quartile, HR for T2D incidence = 0.38 (95% CI: 0.19 to 0.77) for fiber intake, 2.14 (95% CI: 1.16 to 3.92) for fat intake and 1.73 (95% CI: 0.89 to 3.38) for SFA intake, after adjustment for confounding variables.</p>	<p>None.</p>
<p>Lopez S, Bermudez B et al, 2008</p> <p>Study Design: Randomized Crossover Trial</p> <p>Class: A</p> <p>Rating: </p>	<p>14 men (healthy, normotriglyceridemic with normal glucose tolerance).</p> <p>Mean age: 27 years.</p> <p>Mean BMI: 23.9kg/m².</p> <p>Location: Spain.</p>	<p>Four isocaloric diets with 9% ↑ fat (replacing CHO in Step I diet as control):</p> <ol style="list-style-type: none"> 1) Control Step I 2) High butter (MUFA:SFA, 0.48:1.0) 3) Refined olive oil (ROO) (MUFA:SFA, 5.43:1.0) 4) High palmitic sunflower oil (HPSO) (MUFA:SFA, 2.42:1.0) 5) Mixture of vegetable and fish oils (VEFO) (MUFA:SFA, 7.08:1.0). 	<p>High fat meals:</p> <ul style="list-style-type: none"> • ↑ postprandial insulin, TG and FFAs • ↑ pancreatic b-cell activity • ↓ insulin sensitivity. <p>Postprandial insulin sensitivity ↑ and as proportion of MUFA vs. SFA ↑.</p> <p>VEFO>ROO>HPSO>Butter.</p> <p>B-cell activity, measured as early postprandial insulin response, ↓ as proportion of MUFAs vs. SFAs ↑.</p>	<p>Relatively ↓ subject number (N=14).</p>	<p>None.</p>
<p>Paniagua JA, de la Sacristana AG et al, 2007</p> <p>Study Design: Prospective Cohort Study</p> <p>Class: B</p> <p>Rating: </p>	<p>Crossover design.</p> <p>Offspring of obese, T2D patients.</p> <p>59 subjects originally recruited.</p> <p>27 subjects did not meet inclusion criteria.</p> <p>Qualifying subjects underwent OGTT, after which 11 insulin-resistant (IR) subjects (four men, seven women) remained in the study.</p> <p>Subjects had a BMI: 25kg/m².</p> <p>Location: Spain.</p>	<p>Three diet periods; 28 days.</p> <p>Crossover design:</p> <ol style="list-style-type: none"> 1) High SFA: ↑ 15% energy as SFA 2) High MUFA: ↑ 15% energy as MUFA 3) High CHO: ↑ 18% energy as CHO. 	<p>No Δ in BW and REE were with any intervention.</p> <p>↓ fasting serum glucose with MUFA and CHO diet compared with SFA.</p> <p>(5.02±0.1, 5.03±0.1, 5.50±0.2mmol per L, respectively; ANOVA<0.05).</p> <p>MUFA diet.</p> <p>↓ HOMA-IR, compared to CHO and SFA diets (2.32±0.3, 2.52±0.4, 2.72±0.4, respectively, ANOVA<0.01).</p> <p>Compared to CHO breakfast, ↓ AUC postprandial glucose and insulin with MUFA or SFA breakfasts (11.9±2.7, 7.8±1.3, 5.84±1.2mmol x 180 minutes per L, ANOVA<0.05 and 2,667±329, 1,004±147, 1,253±140, pmol x 180 minutes per L, ANOVA<0.01, respectively).</p> <p>↑ fasting and postprandial HDL-C with MUFA and ↓ AUC of TG with CHO diet.</p>	<p>None.</p>	<p>None.</p>

				<p>Fasting proinsulin (PI). No Δ in stimulated PI/I with MUFA.</p> <p>\uparrow GLP-1 with MUFA and SFA breakfasts compared with isocaloric CHO breakfast.</p> <p>\uparrow fasting and postprandial HDL-C with MUFA and \downarrow AUC of TG with CHO diet.</p> <p>\downarrow fasting proinsulin (PI).</p> <p>No Δ stimulated PI/I with MUFA.</p>	
<p>Perez-Jimenez F, Lopez-Miranda J et al, 2001</p> <p>Study Design: Randomized Controlled Trial</p> <p>Class: A</p> <p>Rating: </p>	<p>28-day run-in and dietary periods.</p>	<p>59 normolipidemic subjects (30 men, 29 women).</p> <p>Mean age: 23.1 years.</p>	<p>Dietary information collected over seven consecutive days.</p> <p>Run-in period: All subjects on SFA diet 38% fat (20% SFA).</p> <p>Randomized to two dietary periods:</p> <p>1) MUFA: 38% fat (22% MUFA)</p> <p>2) CHO: 57% CHO, 28% fat (<10% SFA, 12% MUFA).</p>	<p>In comparison to SFA diet, CHO and MUFA diets \downarrow mean plasma LDL-C (P<0.001) and HDL-C (P<0.001).</p> <p>Fasting plasma insulin and non-esterified FA (NEFA) were significantly \uparrow during SFA diet than CHO or MUFA diets.</p> <p>Steady state plasma glucose \downarrow on both CHO and MUFA diets.</p> <p>2-deoxy glucose uptake \uparrow in both CHO (P<0.001) and MUFA (P<0.001) diets.</p> <p>Fasting FFA levels were correlated positively with plasma glucose levels.</p>	None.
<p>Salmeron J, Hu F et al, 2001</p> <p>Study Design: Prospective Cohort Study</p> <p>Class: B</p> <p>Rating: </p>	<p>Nurses' Health Study.</p> <p>14-year follow-up.</p>	<p>98,462 subjects with FFQ data in 1980.</p> <p>Women aged 34 to 59 years.</p> <p>After exclusion, 84,204 Nurses were followed for T2D incidence from 1980 to 1994.</p> <p>Location: United States.</p>	<p>Dietary assessment with validated, semi-quantitative 61-item FFQ in 1980; FFQ expanded to 116 food items in 1984.</p> <p>FFQ administered in 1980, 1984, 1986 and 1990.</p> <p>Two-year follow-up on diabetes diagnosis (exclusion of T1D and gestational diabetes).</p> <p>Criteria for T2D diagnosis was that of National Diabetes Group and WHO.</p>	<p>2,507 cases of T2D in 14-year follow-up.</p> <p>SFA and MUFA intakes associated with \uparrow RR of T2D in age and BMI adjusted analyses.</p> <ul style="list-style-type: none"> • Positive association of SFA with RR for T2D was greatly attenuated with multivariate analysis including all major types of FAs • NS positive association of MUFA and RR for T2D after multivariate analysis. <p>PUFA intake was inversely associated with T2D risk in all analyses.</p> <p>TFA and dietary cholesterol were positively associated with risk of T2D.</p> <p>With isocaloric energy substitutions, substitution of 5% energy from SFA with PUFA resulted in a 35% \downarrow risk of T2D.</p>	None.

				<p>Replacement of 5% SFA with CHO resulted in no Δ in T2D risk.</p> <p>Replacement of 2% energy from TFA with PUFA associated with 40% \downarrow risk of T2D.</p>	
<p>Shah M et al 2007</p> <p>Study Design: Randomized Crossover Trial</p> <p>Class: A</p> <p>Rating: </p>	<p>Three- to four-day intervals (after overnight fast); each subject consumed mixed test meal on four occasions.</p>	<p>11 men with T2D.</p> <p>Mean age: 54.6\pm12.2 years.</p> <p>Location: United States.</p>	<p>All subjects received an isocaloric diet with 15% energy as PRO, 35% as fat and 50% as CHO.</p> <p>The type of fat in test meal varied on each occasion, and was rich in either: 1) Palmitic acid, 2) oleic acid, 3) LA or 4) EPA and DHA.</p>	<p>The insulin response (P=0.0002), but not glucose response, was significantly different between meals.</p> <p>The insulin response was \downarrow in meals rich in oleic acid or EPA and DHA than to meals rich in palmitic acid or linoleic acid (P<0.01).</p> <p>The TG response did not reach statistical significance (P=0.06), but tended to be \downarrow with DHA+EPA than in meals rich in the other FAs.</p> <p>Oleic acid or EPA+DHA may modestly \downarrow the insulin response in T2D patients, without harming glucose tolerance.</p>	<p>Small sample size.</p>
<p>St-Onge MP et al 2003</p> <p>Study Design: Randomized Crossover Trial</p> <p>Class: A</p> <p>Rating: </p>	<p>Subjects were enrolled in two dietary phases of 27 days each, separated by a four- or eight-week washout of habitual diet.</p>	<p>22 overweight women.</p> <p>Mean age: 44.3\pm3.8 years.</p> <p>17 subjects completed trial.</p> <p>Location: Canada.</p>	<p>All meals were provided and diets contained 40% energy as fat, 15% energy as PRO and 45% energy as CHO.</p> <p>During the long chain triglyceride (LCT) phase, 75% of fat was from beef tallow or a blend of SFA and unsaturated vegetable oils.</p> <p>During the MCT phase, 50% of fat was provided by MCT oil, 10% by olive oil and 5% by butter, coconut oil and flaxseed oil.</p>	<p>NS differences between diet phases in total and subcutaneous adipose tissue volumes.</p> <p>Average energy expenditure (EE) and fat oxidation were greater during MCT than LCT consumption.</p> <p>0.95\pm0.019 vs. 0.90\pm0.024kcal per minute for EE P<0.05.</p> <p>0.080\pm0.0026 vs. 0.075\pm0.0022g per minute for fat oxidation, P<0.05.</p> <p>Results show that long-term consumption of MCT enhances EE and fat oxidation in obese women compared to LCT consumption.</p> <p>MCT may \uparrow weight loss due to increased EE.</p>	<p>None.</p>
<p>Vessby B et al 2001</p> <p>Study Design: Randomized Controlled Trial</p> <p>Class: A</p> <p>Rating: </p>	<p>Part of the KANWU study.</p> <p>Three months, preceded by a two-week stabilization period.</p>	<p>162 adults (86 males, 76 females)</p> <p>Age: 30 to 65 years.</p> <p>Location: Five centers (Sweden, Italy, Finland, Denmark and Australia).</p>	<p>Subjects were randomized to diets comprised of 37% energy (E) from fat as either high SFA or high MUFA.</p> <p>SFA %E 17%\pm8%.</p> <p>Within groups, there was a second assignment to fish oil (3.6g n-3 FA per day) capsules or olive oil-placebo capsules.</p>	<p>Insulin sensitivity was significantly impaired on SFA diet (-10%, P=0.03), but did not Δ on MUFA diet (+2%, NS). Difference between diets was statistically significant (P=0.05).</p> <p>Insulin sensitivity was 12.5% \downarrow on the SFA diet and 8.8% \uparrow on the MUFA diet (P=0.03).</p> <p>Beneficial effects only seen at a total fat intake <37% of energy.</p>	<p>None.</p>

				<p>Insulin secretion was not affected.</p> <p>The addition of n-3 fatty acids did not influence insulin sensitivity or secretion.</p> <p>LDL-C ↑ on the SFA diet (+4.1%, P <0.01), but ↓ on the MUFA diet (-5.2%, P <0.001).</p> <p>Lipoprotein (a) ↑ by 12% on the MUFA diet (P <0.001).</p>
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Research Design and Implementation Rating Summary

For a summary of the Research Design and Implementation Rating results, [click here](#).

Worksheets

- [Azadbakht L, Mirmiran P, Hedayati M, Esmailzadeh A, Shiva N, Azizi F. Particle size of LDL is affected by the National Cholesterol Education Program \(NCEP\) step II diet in dyslipidaemic adolescents. *Br J Nutr*. 2007 Jul; 98 \(1\): 134-139. Epub 2007 Apr 20.](#)
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- [Galgani JE, Uauy RD, Aguirre CA, Díaz EO. Effect of the dietary fat quality on insulin sensitivity. *Br J Nutr*. 2008 ;100\(3\):471-9.](#)
- [Han JR, Deng B, Sun J, Chen CG, Corkey BE, Kirkland JL, Ma J, Guo W. Effects of dietary medium-chain triglyceride on weight loss and insulin sensitivity in a group of moderately overweight free-living type 2 diabetic Chinese subjects. *Metabolism*. 2007 Jul;56\(7\):985-91.](#)
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