

Original Article

Effect of palm oil consumption on plasma lipid concentrations related to cardiovascular disease: a systematic review and meta-analysis

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Background and Objectives: The precise association between palm oil consumption and lipid-related cardiovascular disease risk remains unclear. A systematic review was thus performed to assess whether palm oil consumption has a negative effect on plasma lipid-related cardiovascular disease marker levels. **Methods and Study Design:** In June 2018, the electronic bibliographic databases PubMed, EMBASE (Ovid), the Cochrane Library (Ovid) and the Chinese National Knowledge Infrastructure were searched and a total of 11 eligible dietary intervention articles involving 961 volunteers were selected. Both random and fixed effect models were used to calculate pooled weighted mean differences (WMD). **Results:** A total of 11 articles involving 547 participants met the inclusion criteria. The pooled analysis revealed that palm oil increased the concentration of High-density lipoprotein cholesterol (WMD: 0.15 mmol/L; $p < 0.00001$). Palm oil consumption had no significant effects on blood total cholesterol [WMD: -0.01 mmol/L; $p = 0.82$] and LDL-c [WMD: -0.05 mmol/L; $p = 0.10$] and triglyceride concentrations [WMD: 0.00 mmol/L; $p = 0.96$], relative to the effects of unsaturated fatty acid consumption. Subgroup analyses revealed that palm oil has a beneficial effect on High-density lipoprotein cholesterol levels when more than 30% of total dietary energy was constituted by fat. **Conclusions:** This review revealed that palm oil does not induce increases in cardiovascular disease risk-related biomarkers relative to unsaturated fatty acids. Furthermore, larger-scale samples of human dietary intervention trials are required to increase the accuracy of meta-analyses.

Key Words: palm oil, meta-analysis, plasma lipid, fatty acid, cardiovascular disease

INTRODUCTION

It is estimated that cardiovascular disease (CVD), a non-communicable disease, accounts for 31% of deaths globally, and more than 75% of all CVD cases occur in low- and middle-income countries.^{1,2} Recently, mortality rates related to CVD have reached a new maximum, exceeding those of cancer and other well-known diseases. It has been estimated that nearly 290 million people are diagnosed with CVD in China.³ The relationship between diet and health has raised considerable concern in recent years, especially where the connection between the dietary fat contents of edible oils and CVD risk is concerned.⁴ A major debate published in high-visibility journals has recently discussed whether consuming high amounts of saturated fatty acids could increase CVD risk. A study conducted by a cohort of people over a period of 20 years demonstrated that those with higher dietary intakes of major saturated fatty acids had an increased risk of developing coronary heart disease.⁵

Palm Oil (PO) is a vegetable oil harvested from the

fruits of the tropical tree species *Elaeis guineensis*. Half of the primary constituents of PO are saturated fatty acids (45% palmitic acid and 5% stearic acid), which are often considered to increase an individual's risk of developing cardiovascular disease when featuring prominently in their diet.

The results of a randomized controlled trial (RCT) performed by a prior study suggest that compared to the consumption of mono-unsaturated fatty acids (MUFAs), PO consumption would only moderately increase the concentration of plasma low-density lipoprotein cholesterol

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(LDL-c) in the blood,⁶ similar to the findings of another prior study.⁷ However, it has also been well-established that, when compared to the poly-unsaturated fatty acids (PUFAs), PO reduced plasma LDL-c concentrations.⁸ PO consumption has thus been reported to have both positive and negative effects on the concentrations of CVD-related markers.⁹ A prior meta-analysis concluded that saturated fat consumption was not associated with increased CVD risk in prospective cohort studies.¹⁰ In addition, Sun and colleagues have reported that PO consumption significantly increased LDL-c levels in RCTs based on a meta-analysis.¹¹ Whether PO consumption could elevate plasma total cholesterol (TC) and LDL-c concentrations in healthy individuals, which are both related to elevated CVD risk, remains unclear. Therefore, the purpose of this study was to assess the effects of PO consumption on plasma lipid profiles and evaluate its effect on CVD risk.

METHODS

Search strategy

A systematic search of electronic bibliographic databases of PubMed, Embase (Ovid), Cochrane Library (Ovid), China National Knowledge Infrastructure (CNKI) and manual search all relative references updated on June 2018. Reference list were also checked and included the qualified studies. English and Chinese written articles were selected. A predefined search strategy was conducted using a combination of the following terms: palm oil (PO), palmitic acid, palm olein, plasma lipid and CVD. Two reviewers independently searched literatures according to the inclusion criteria. Discrepancies were resolved by discussion or judged by a third author.

Criteria for inclusion

Articles were selected according to following eligible criteria: (1) Articles were randomized controlled trials (RCTs). (2) Articles were in comparison PO-rich diets with a controlled diet rich in MUFA or PUFA. (3) The intervention period was lasted for more than two weeks. It has been proved that blood lipid profile come up to a new stable equilibrium circumstance for two weeks.^{12,13} (4) Subjects all with normal serum cholesterol concentrations. (5) Participants without any metabolic syndrome or a medical history of coronary artery disease, which would increase 20% higher risk of suffering from CVD after the next ten years which was assessed by the Framingham risk score.¹⁴ (6) Subjects were without taking any form of medicine such as oral contraceptives.¹⁵

Data collection

Two authors retrieved data independently. Extracted information was as follows: first author, publication year, nation, sample size, population characteristics, age, body-mass index (BMI), study design, the type of randomization and blinding, duration of follow-up and wash out, amount of oil intake, founding source and the values of blood lipid profiles. TC and LDL-c were the primary outcome indicators, HDL-c and triglyceride (TG) were secondary outcome indicators. The means and standard deviations (SDs) were extracted and input into a pre-structured data extraction form. When there was disagreement, we invited another expert to judge.

Risk of bias assessments

We elucidated risk of bias of all eligible literatures based on Cochrane Collaboration's risk-of-bias tool.¹⁶ Each one was judged as low, unclear or high risk based upon the following items: adequacy of selection bias (random sequence generation, allocation concealment), performance bias (blinding of participants and personal), detection bias (blinding of outcome assessment), attrition bias (incomplete data outcome), reporting bias (selective reporting) and other bias (e.g. funding support).

Statistical analysis

All outcomes were recorded as continuous data, and the effect size (ES) was calculated by statistic the weighted mean differences (WMDs) with 95% confidence intervals (CIs). Heterogeneity was investigated using Chi^2 , p value and I^2 statistic. If heterogeneity was more than 50% ($I^2 > 50%$) a random-effect model was used to pool the data, conversely a fixed-effect model. Subgroup and meta-regression analyses were also performed. A sensitivity analysis was to explore possible source of heterogeneity whether any one research influenced the overall pooled estimate. Through this process, we omitted a single research and judged if it had the influence on the overall pooled examine.

All meta-analyses were conducted using Review Manager (RevMan) version 5.3 (Cochrane Collaboration) and STATA statistical software (version 15.0 SE; Stata Corp). All exams were 2-tailed, and p value less than 0.05 was regarded to have statistically significant. We converted values for TC, LDL-c, and HDL-c from mg per dL to mmol per liter by multiplying by 0.0259 and the value of TG was 0.0113.

RESULTS

Characteristics of included studies

The initial literature search yielded 2216 articles. After deleting duplicates and excluding titles and abstracts, a total of eighteen articles were considered potentially relevant and reviewed full-text. Ultimately, eleven articles met the inclusion criteria for the meta-analysis.¹⁷⁻²⁷ Excluded articles were as follows: two studies mixed PO and other types of oil;^{28,29} One trial involved patients had coronary heart disease and took medicine;³⁰ Four studies involved subjects took oral contraceptives during the study.³¹⁻³⁴ In one literature, both two control groups met the requirement, so the data were analysed as two separate articles were generated consequently. We performed the process iteratively until all eligible articles could be identified. A specific process of literature search flowchart is shown in Figure 1. The main characteristics of the included studies are exhibited in Table 1.

Risk of bias assessment

The risk of bias assessment of all included trails was exhibited detailed in Figure 2 and Figure 3. All trials were assessed by low, high or unclear risk. Unclear risk of bias in most risk of bias domains of the eleven included articles. All trials were judged to be of unclear risk in selection bias domain in default of further information on random sequence generation in detail. Four trials^{18,20,21,27} clearly stated the blinding of the participants. With regard

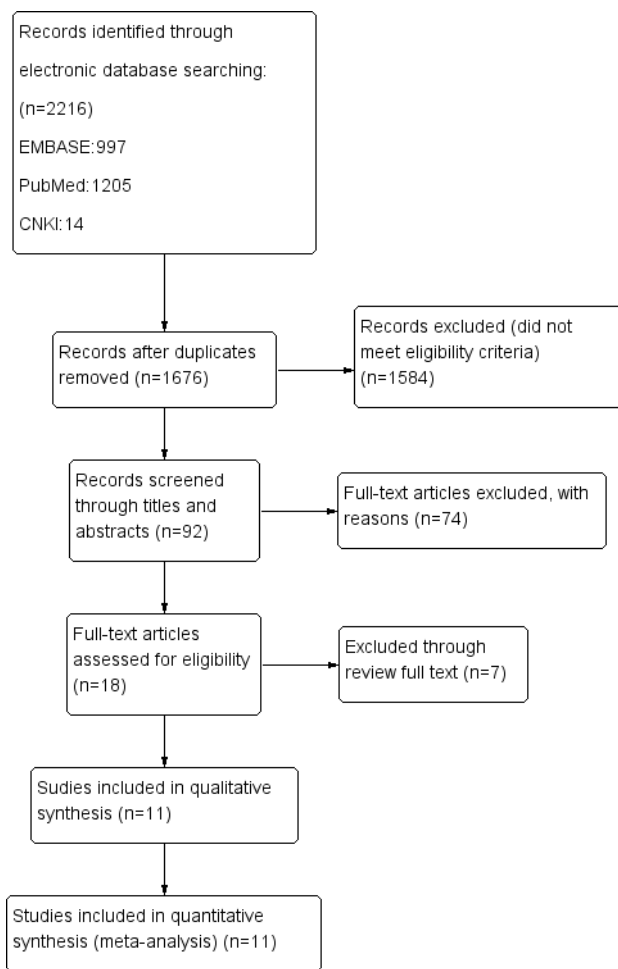


Figure 1. Flowchart of study selection

to other bias, we assessed low risk of bias in this domain as they all were supported uniformly.

Meta-analyses

The results of intervention studies that aimed to examine the effects of PO consumption relative to unsaturated fatty acid (UFA) consumption on blood lipid parameters are shown in Figure 4.

Pooled data from 12 trials disclosed a significant effect of PO consumption on the serum concentration of HDL-c

[WMD: 0.15 mmol/L (95% CI: 0.13, 0.16), $I^2=93%$; $p<0.0001$]. Highly significant heterogeneity was observed between the results of all twelve trials. A meta-analysis of the pooled data revealed no significant effects of PO consumption (relative to UFA consumption) on blood TC [WMD: -0.01 mmol/L (95% CI: -0.08, 0.07), $I^2=26%$; $p=0.82$] and LDL-c [WMD: -0.05mmol/L (95% CI: -0.11, 0.01), $I^2=21%$; $p=0.10$] and TG levels [WMD: 0.00 mmol/L (95% CI: -0.07, 0.08), $I^2=77%$; $p=0.96$].

Subgroup analyses

To evaluate potential sources of bias, subgroup analyses were performed to assess the potential effects of PO on HDL-c levels (Figure 5). Based on data from five studies compared with MUFA, PO consumption had no significant effect on blood HDL-c concentration [WMD: -0.00 mmol/L (95% CI: -0.04, 0.04), $I^2=0%$; $p=1.00$]. Furthermore, no significant differences were observed with respect to blood HDL-c [WMD: 0.07 mmol/L (95% CI: -0.02, 0.15), $I^2=93%$; $p=0.13$] compared with PUFA. Based on pooled data from four studies that used a wash-out period, there was no significant effect of PO consumption on blood HDL-c concentration [WMD: 0.02 mmol/L (95% CI: -0.02, 0.06), $I^2=34%$; $p=0.29$]. Based on pooled data from 8 studies that did not use a washout period, there was no significant effect of PO consumption on HDL-c [WMD: 0.06 mmol/L (95% CI: -0.03, 0.14), $I^2=90%$; $p=0.20$]. A pooled analysis of seven studies using a crossover design disclosed no significant effect of PO consumption on blood HDL-c [WMD: 0.02 mmol/L (95% CI: -0.01, 0.05), $I^2=0%$; $p=0.21$]. In addition, a pooled analysis of five studies not utilizing a crossover design uncovered no significant effect of PO consumption on blood HDL-c [WMD: 0.09 mmol/L (95% CI: -0.01, 0.19), $I^2=91%$; $p=0.08$].

A pooled analysis of data from five studies in which at least 30% of subjects' total dietary energy was provided by fat showed a significant effect of PO consumption on blood HDL-c [WMD: 0.04 mmol/L (95% CI: 0.00, 0.07), $I^2=0%$; $p=0.03$]. A pooled analysis of seven studies in which less than 30% of subjects' total dietary energy was provided by fat showed no significant effect of PO consumption on blood HDL-c [WMD: 0.05 mmol/L (95%

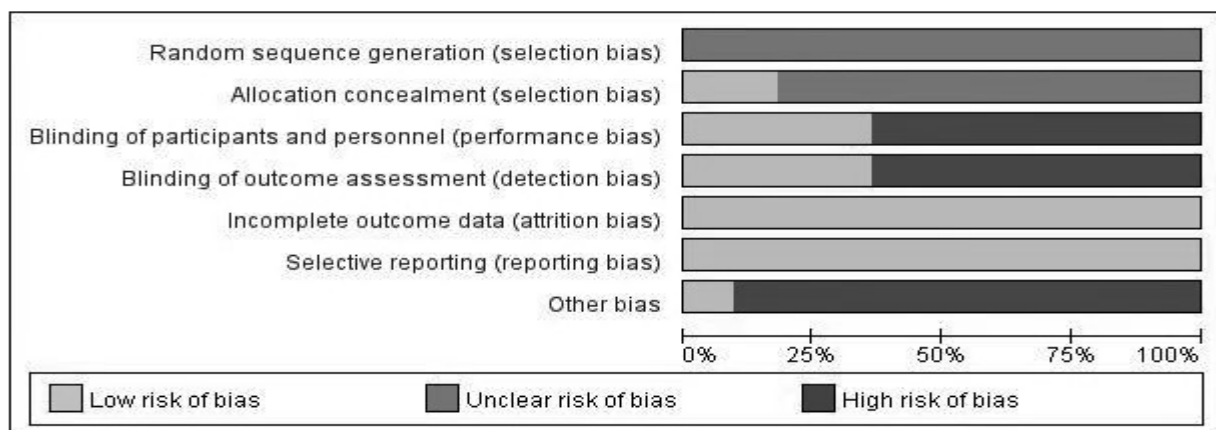


Figure 2. Risk of bias graph. Across-over trials, information is either from trials at a low risk of bias (light grey), or from trials at unclear risk of bias (dark grey), or from trials at high risk of bias (black).

Table 1. Characteristics of the RCTs comparing palm oil with unsaturated fatty acid

Author Publication year	Country	No. of subjects		Mean age (y) [†]	BMI (kg/m ²)	Study design	Duration of follow-up (week)	Type of test oil	Test oil %EN level	Diet fat EN% level	Wash out (week)	Founding source
		Men	Women									
Sun 2018	China	47	53	41.3±8.36	22.0±1.90	Randomized Crossover Double Blind	5	Palm oil Olive oil	20%	30%	2	MPOB
Voon 2011	Malaysia	9	36	30.1±8.3	23.1±3.7	Randomized Crossover 3×3Latin square-design	5	Palm oil Olive oil	20%	30%	Not Reported	MPOB
Sundram 1997	Malaysia	18	9	29.4±4.6	22.7±2.59	Randomized Crossover Double Blind	4	Oleic acid Palm oil	20%	31%	Not Reported	MPOB
Sundram 1995	Malaysia	23	-	22±4	21.3±1.7	Randomized Cross-over Double-blind	4	Canola oil Palm oil	20%	31%	Not Reported	MPOB
Ng 1992	Malaysia	20	13	30±4.5	22.3±2.	Randomized Controlled Crossover	6	Palm oil Olive oil	23%	34%	Not Reported	MPOB
Wood 1993	US	29	-	41±8	83.5±10 [§]	3×3Latin square-designed Crossover	6	Palm oil Sunflower oil	24%	40%	6	MPOB
Ghafoorunissa 1995	Indian	12	-	35±1.1	21±0.8	Cross-over	8	Palm oil Groundnut oil	17.50%	27%	6	MPOB
Zhang 1997	China	120	-	18-25	18.5-25	Randomized parallel control test	6	Palm oil Soybean oil Peanut oil	24%	30%	Not Reported	MPOB
Marzuki 1991	Malaysia	110	-	16-17 [‡]	51.7±0.7 [§]	before-after study	5	Palm oil Soybean oil	Not Reported	36%	6	University of Kebangsaan
Zhang 1996	China	45	-	18-25 [‡]	66 [§]	Randomized parallel control test	6	Palm oil Soya oil	24%	30%	Not Reported	MPOB
Ng 1991	Malaysia	61	22	20-34 [‡]	19.5±2	Randomized double blind parallel control test	5	Palm oil Corn oil	22.5%	30%	Not Reported	MPOB

BMI: body mass index; EN: energy; MPOB: Malaysian Palm Oil Board

[†]Data expressed as M±SD.[‡]Data expressed as average[§]Data expressed as weight (kg)

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Ghafoor 1995	?	?	-	-	+	+	-
Marzuki 1991	?	?	-	-	+	+	+
Ng 1991	?	+	+	+	+	+	-
Ng 1992	?	?	-	-	+	+	-
Sun 2018	?	?	+	+	+	+	-
Sundram 1995	?	?	+	+	+	+	-
Sundram 1997	?	?	+	+	+	+	-
Voon 2011	?	+	-	-	+	+	-
Wood 1993	?	?	-	-	+	+	-
Zhang 1996	?	?	-	-	+	+	-
Zhang 1997	?	?	-	-	+	+	-

Figure 3. Risk of bias summary: review authors' judgments about each risk of bias item for each included trial

CI: -0.05, 0.15), $I^2=94\%$; $p=0.32$].

A pooled analysis of five studies in which fat less than 20% was provided by PO demonstrated no significant difference on blood HDL-c concentration [WMD: -0.00 mmol/L (95% CI: -0.04, 0.04), $I^2=0\%$; $p=0.85$]. A pooled analysis of six studies in which fat more than 20% was provided by PO showed no significant effect on blood HDL-c concentration [WMD: 0.07 mmol/L (95% CI: -0.02, 0.17), $I^2=94\%$; $p=0.12$].

Subgroup analyses were also performed to assess the potential effect of different study protocols on the results of TG analyses (Figure 6). A pooled analysis of five studies showed no significant differences with respect to blood TG [WMD: 0.01 mmol/L (95% CI: -0.06, 0.08), $I^2=0\%$; $p=0.82$]. No significant effect on blood TG was observed with respect to blood TG [WMD: -0.00 mmol/L (95% CI: -0.11, 0.11), $I^2=85\%$; $p=0.98$]. Pooled data from four studies using a washout period showed a significant effect on TG concentration [WMD: 0.08 mmol/L (95% CI: 0.01, 0.16), $I^2=37\%$; $p=0.04$]. Pooled data from 8 studies, which did not use a washout period revealed no significant effect on TG [WMD: -0.06 mmol/L (95% CI:

-0.15, 0.04), $I^2=66\%$; $p=0.24$]. A pooled analysis of seven studies utilizing a crossover design disclosed no significant effect on blood TG [WMD: 0.05 mmol/L (95% CI: -0.01, 0.11), $I^2=13\%$; $p=0.10$]. A pooled analysis of five studies, which did not utilize a crossover design, showed no effect on blood TG [WMD: -0.02 mmol/L (95% CI: -0.20, 0.16), $I^2=87\%$; $p=0.81$]. A pooled analysis of five studies with total dietary energy provided more than 30% by fat showed a significant difference on blood TG [WMD: 0.04 mmol/L (95% CI: 0.01, 0.19), $I^2=28\%$; $p=0.03$]. A pooled analysis of seven studies in which less than 30% of subjects' total dietary energy was provided by fat uncovered no significant effect on TG [WMD: -0.05 mmol/L (95% CI: -0.13, 0.03), $I^2=68\%$; $p=0.19$]. A pooled analysis of five studies with $\leq 20\%$ fat came from PO demonstrated no significant effect on blood TG [WMD: 0.02 mmol/L (95% CI: -0.05, 0.09), $I^2=5\%$; $p=0.57$]. A pooled analysis of six studies in which $>20\%$ fat came from PO showed no significant difference on blood TG [WMD: -0.05 mmol/L (95% CI: -0.17, 0.07), $I^2=83\%$; $p=0.40$].

Meta-regression

Meta-regression analyses were used to assess the potential association between changes in blood parameters (HDL-c and TG) and potential confounders, including covariates (Table 2). The investigated covariates had no effect on HDL-c and TG.

Sensitivity analyses

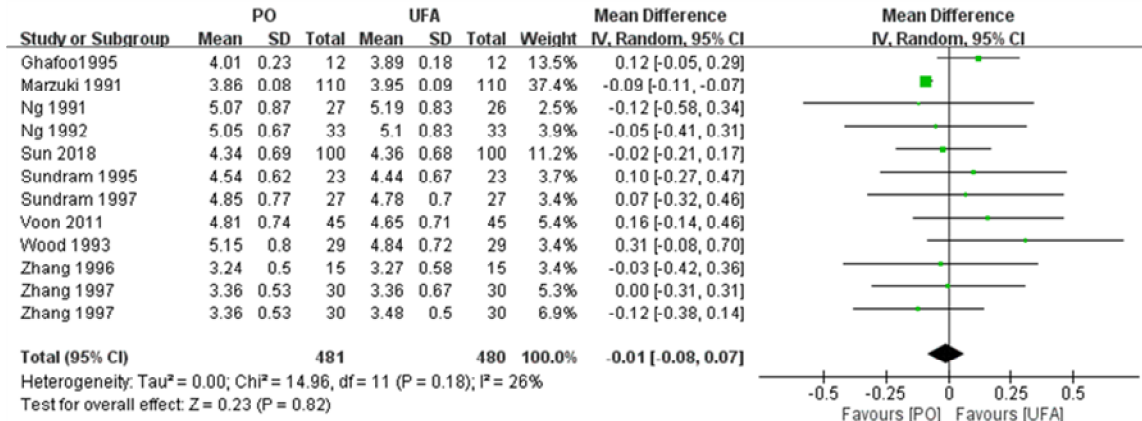
We evaluated sources of sensitivity by sequentially including and excluding trials from the analysis. With regard to HDL-c, after excluding one study³⁵ the pooled effect varied from 0.04 mmol/L (95% CI: -0.03, 0.11; heterogeneity: $I^2=93\%$, $p=0.25$) to 0.03 mmol/L (95% CI: 0.00, 0.05; heterogeneity: $I^2=0\%$, $p=0.02$). The study was published in Chinese and thus differed from the others, which were published in English. This process was then repeated using TG data. We found that the removal of any of the studies from the analysis had a significant impact on TG variance.

DISCUSSION

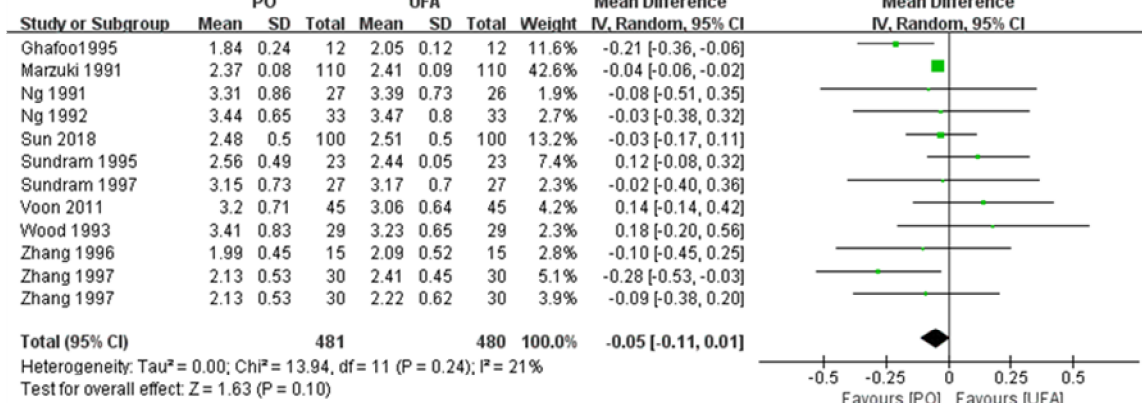
PO consumption is surrounded in plenty of controversy, in part due to its higher saturated fatty acid (SFA) content relative to other UFA oils including olive oil, canola oil, and soybean oil.³⁶ In this meta-analysis, PO consumption had a beneficial effect on serum HDL-c concentration. Meanwhile, PO consumption was not significantly related to TC, LDL-c, and TG concentrations relative to UFA data. Nonetheless, the heterogeneity of the studies used in our analyses varied notably, often reporting relationships between PO consumption and blood HDL-c and TG concentrations.

Sensitivity analyses suggested that the included studies typically reported highly similar results in regard to the effect of PO consumption on blood HDL-c concentration after the exclusion of the Chinese study. In contrast, sensitivity analyses of blood TG data demonstrated that the exclusion of any of the included studies affected the results. It is likely that this could be due to inconsistent experimental design, variation in the duration of interven-

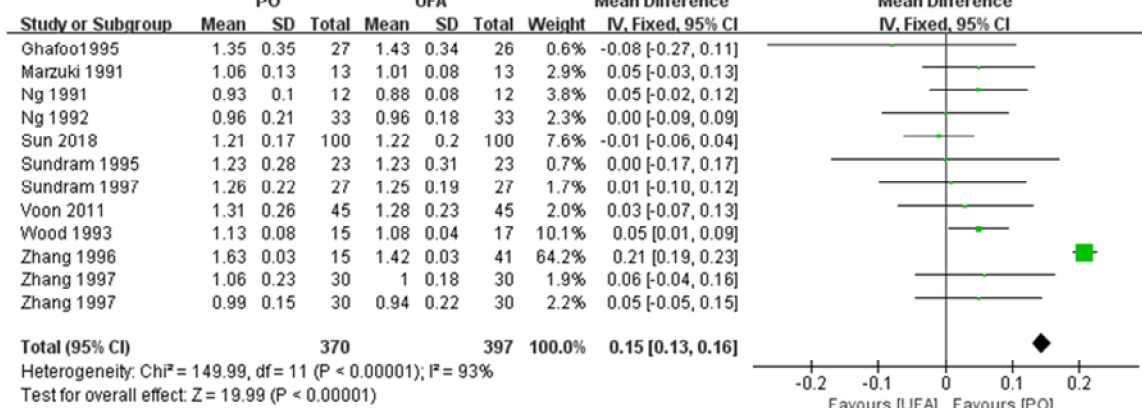
Total cholesterol



LDL-c



HDL-c



Triglycerides

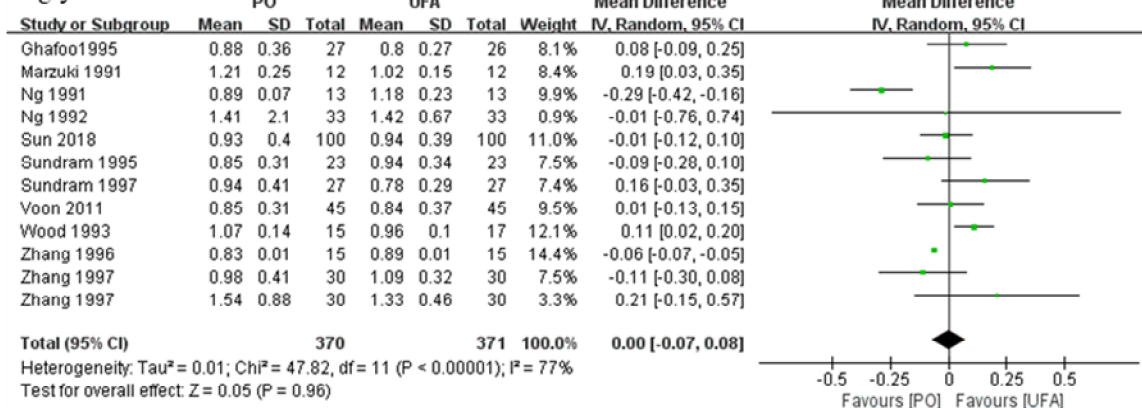


Figure 4. Forest plot displaying weighted mean differences (WMD) and 95% CIs for the effect of PO consumption on blood lipid parameters concentration of Total cholesterol, LDL-c, HDL-c and Triglycerides

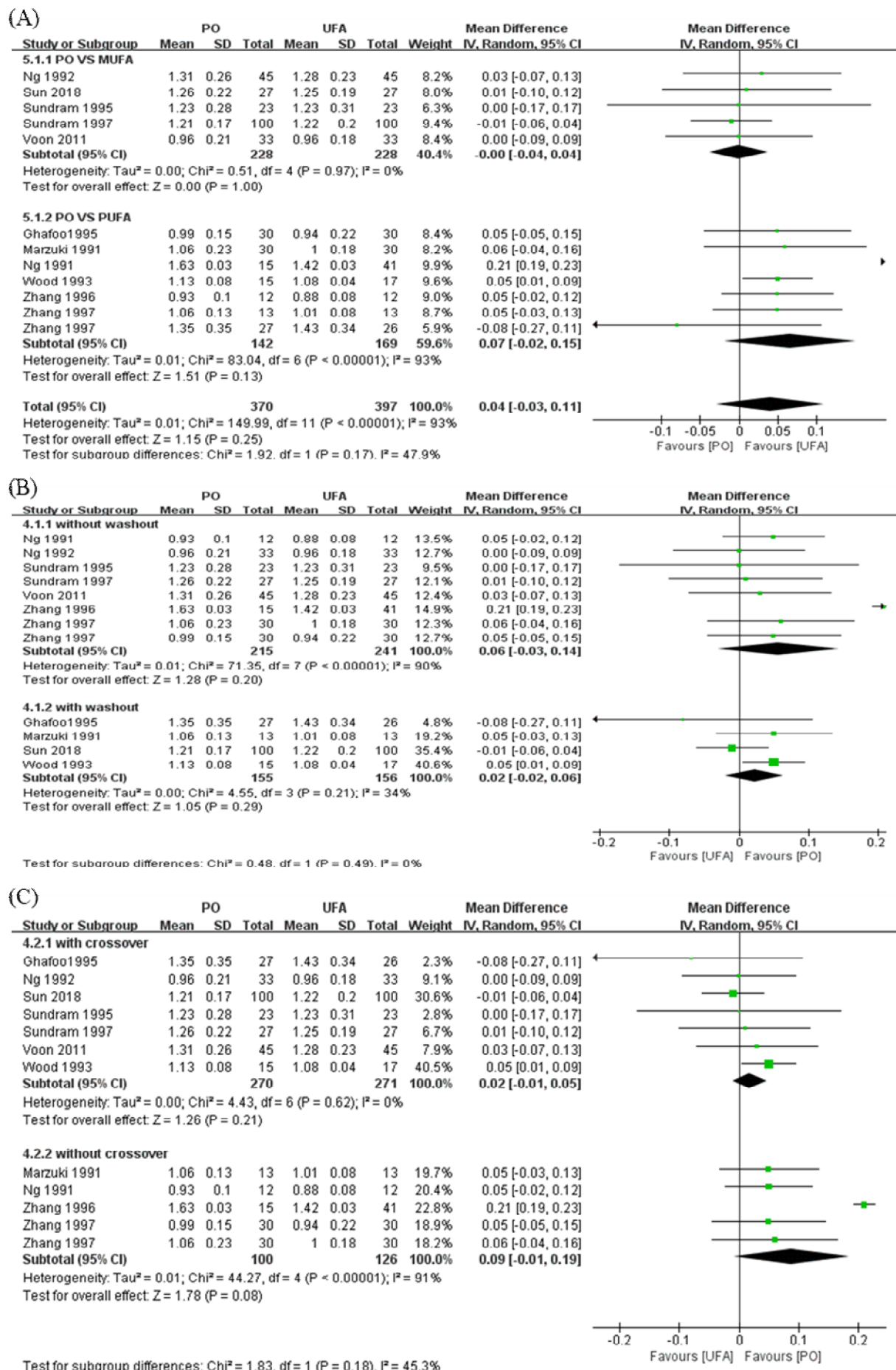


Figure 5. Subgroup analysis for the effect of PO consumption on blood HDL-c concentration. A: MUFA vs. PUFA. B: without washout vs. with washout. C: with crossover vs. without crossover. D: total dietary energy provided by fat 30% or less vs. more than 30%. E: dietary fat provided by PO 20% or less vs. more than 20%.

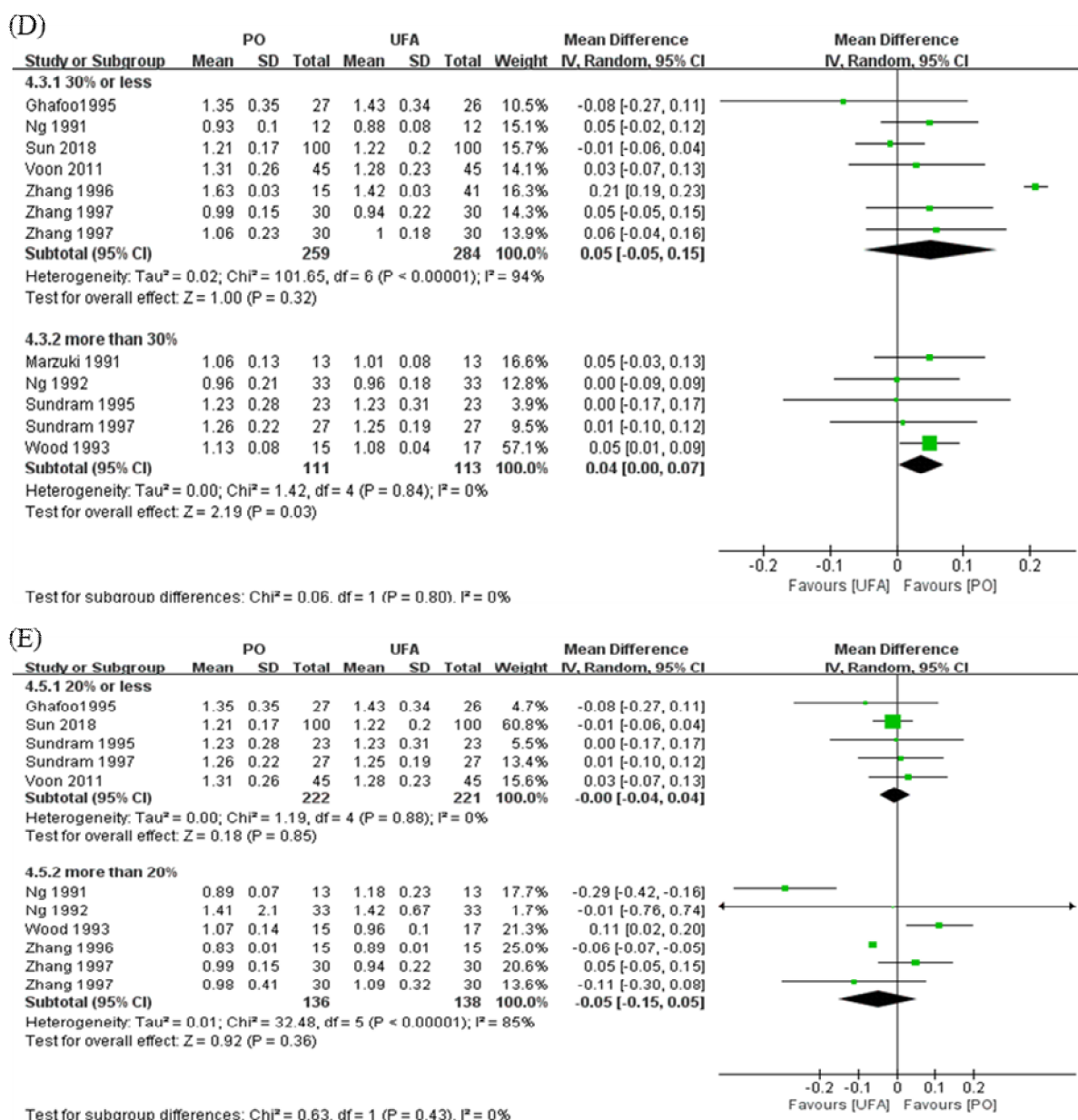


Figure 5. Subgroup analysis for the effect of PO consumption on blood HDL-c concentration. A: MUFA vs. PUFA. B: without washout vs. with washout. C: with crossover vs. without crossover. D: total dietary energy provided by fat 30% or less vs. more than 30%. E: dietary fat provided by PO 20% or less vs. more than 20%. (cont.)

tion (from 4–8 weeks), or variation in the amount of PO used (which varied from 17.5% to 24%) in the assessed studies. Total dietary energy provided by fat was also inconsistent among studies.

Subgroup analyses demonstrated that the positive effect of PO consumption on HDL-c concentration was only observed when fat made up more than 30% of total dietary energy and that the effect was statistically significant. HDL-c concentration is associated with decreased CVD risk.³⁷ PO consumption can induce increases in HDL-c levels according to the results of our analyses, consistent with a previous study³⁸ and another recent meta-analysis.¹⁰ It has been proposed that increases in plasma HDL-c levels may be associated with the elevation of lecithin-cholesterol-acyl-transferase activity.³⁹ The possible proposed mechanism for this process postulates that SFAs inhibit cholesterol ester pool formation and increase the cholesterol regulatory pool, leading to reductions in

receptor mRNA concentrations and partially suppressing the activity of low density lipoprotein receptor.⁴⁰

We found no significant differences between the results of studies in the PO group and those in the MUFA group. This result has highly reliable and thus we can conclude that PO has a similar effect on blood lipids to MUFAs. Subgroup analyses and meta-regression analyses showed that the following influence factors had no impact on the results of HDL-c and TG concentration analyses when comparing studies using PO, MUFAs or PUFAs, crossover, washout period, PO at levels constituting less or more than 20% of dietary fat, and dietary fat at levels constituting less than 30% of total dietary energy.

To our knowledge, the results of studies of PO consumption thus far are inconclusive. According to Keys' equation, palmitic acid has been proven to increase plasma LDL-c and TC concentrations.^{7,41–43} Palmitic acid is strongly associated with CVD-related mortality and has a greater effect on the development of arterial thrombosis

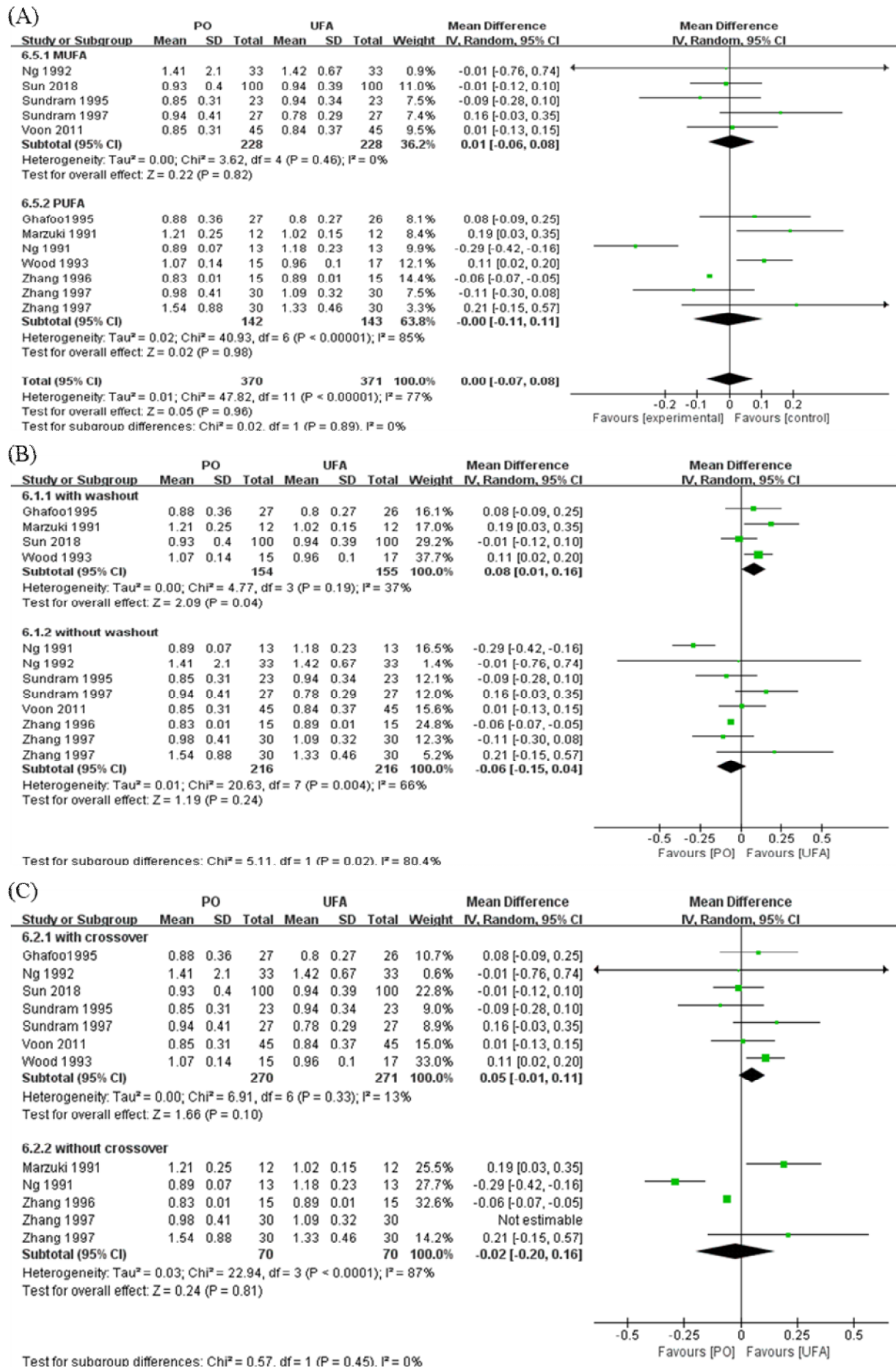


Figure 6. Subgroup analysis for the effect of PO consumption on blood triglycerides concentration. A: MUFA vs. PUFA. B: without washout vs. with washout. C: with crossover vs. without crossover. D: total dietary energy provided by fat 30% or less vs. more than 30%. E: dietary fat provided by PO 20% or less vs. more than 20%.

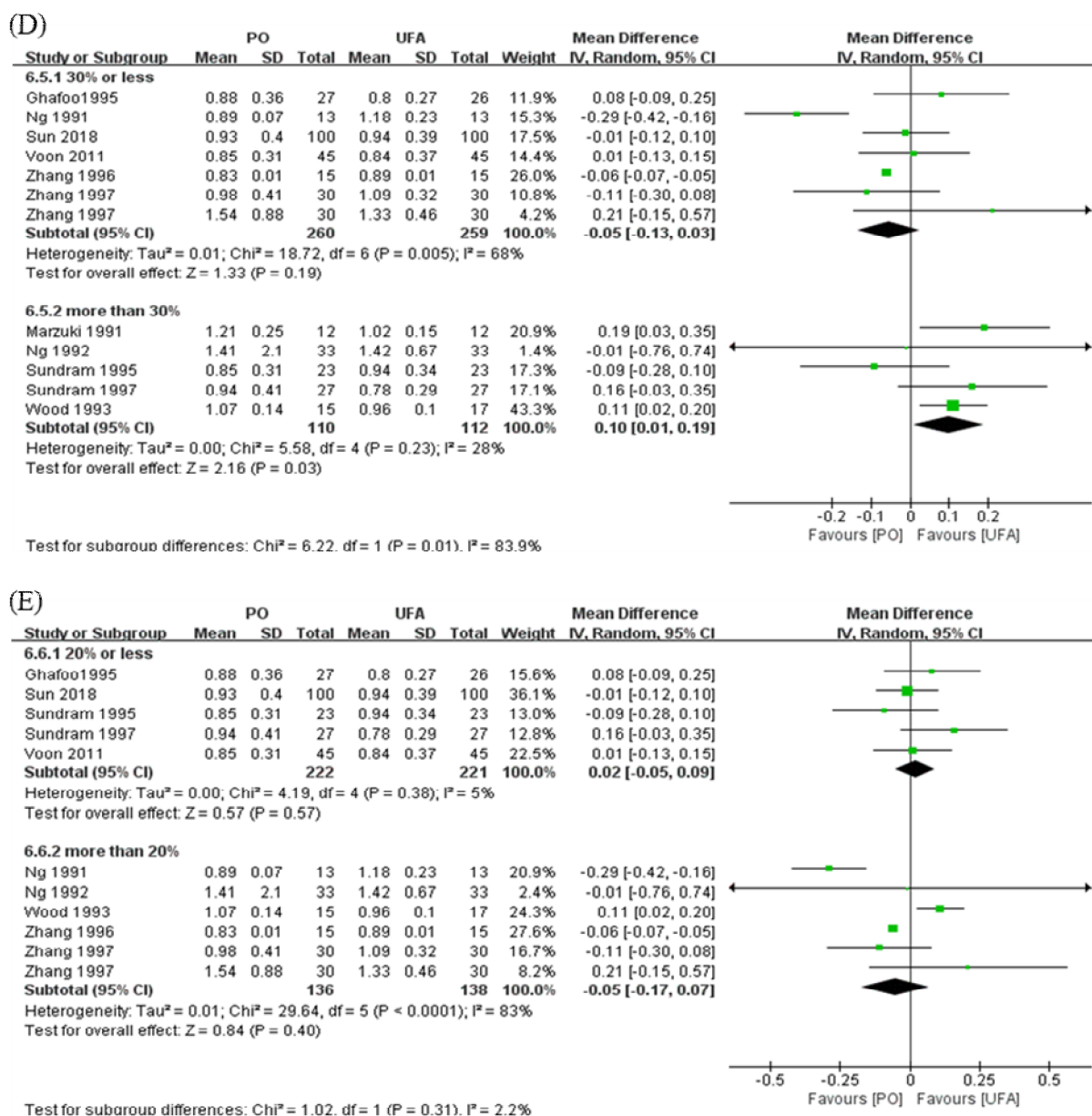


Figure 6. Subgroup analysis for the effect of PO consumption on blood triglycerides concentration. A: MUFA vs. PUFA. B: without washout vs. with washout. C: with crossover vs. without crossover. D: total dietary energy provided by fat 30% or less vs. more than 30%. E: dietary fat provided by PO 20% or less vs. more than 20%. (cont.)

Table 2. Meta-regression analysis of heterogeneity in HDL-c and triglycerides

Independent variable	Dependent variable					
	HDL-c			Triglycerides		
	β (95% CI)	SE	<i>p</i> value	β (95% CI)	SE	<i>p</i> value
Year of publication	0.00 (-0.01, 0.00)	0	0.51	0.00 (-0.01, 0.01)	0	0.97
Country	0.02 (-0.07, 0.03)	0.02	0.36	0.00 (-0.07, 0.12)	0.04	0.60
Design	0.00 (-0.03, 0.02)	0.01	0.56	0.01 (-0.06, 0.04)	0.02	0.62
Washout	0.04 (-0.04, 0.11)	0.03	0.29	0.07 (-0.21, 0.07)	0.06	0.30
Test oil percent	0.04 (-0.01, 0.08)	0.02	0.08	0.01 (-0.07, 0.10)	0.04	0.74
Fat percent	0.01 (-1.54, 1.55)	0.69	0.99	1.60 (-0.94, 4.06)	1.10	0.20
Duration	0.00 (-0.05, 0.07)	0.03	0.74	0.01 (-0.08, 0.11)	0.04	0.72

β : coefficient; SE: standard error.

through various metabolic pathways, relative to UFAs.⁴⁴ A prior study has shown that study participants that consumed a large amount of palmitic acid experienced a higher risk of suffering from coronary artery disease.⁴⁴ This finding confirms that when palmitic acid is a prima-

ry feature in the composition of serum cholesterol esters and phospholipids, an individual's risk of CHD increases.⁴⁵ Bonanome A and colleagues⁴⁶ have reported that, compared to diets containing large amounts of oleic acid, diets containing a large amount of palmitic acid induced

elevations in plasma TC and LDL-c levels. The results of our meta-analysis were not in agreement with this conclusion. In addition to containing half the amount of saturated fat, PO is also a rich source of vitamin E and other antioxidants.⁴⁷

This review complements and strengthens the conclusions of prior studies, albeit being based on stricter inclusion criteria. All of the studies we analyzed were performed using healthy individuals with normal cholesterol levels without hypercholesterolemia. Prior research has demonstrated that those with higher baseline cholesterol levels are more sensitive to dietary changes than those with normal cholesterol levels.^{48,49} Further, we excluded studies using patients and participants prescribed oral contraceptives from our study.^{33,50,51} It has been reported that oral contraceptives significantly affect lipid metabolism and can increase TC and TG levels,⁵² which was demonstrated by Cochrane review.¹⁵ We observed no significant differences in reported TC and LDL-c levels in our results based on the inclusion of studies using PO and UFAs. Therefore, we can be sure that our results are stable and reliable.

Our analyses were limited in several ways. Bias in the selection of literature may have affected our results. On the other hand, the subjects were too young to be sensitive to CVD. We concluded that studies of PO consumption were overall inconclusive, however this may be due to the inherent limitations and heterogeneity of the analyzed studies themselves. Lastly, it is difficult to arrive at a unified conclusion based on short-term dietary studies. Further studies are required that include more long-term data from more rigorous studies to clarify whether PO consumption affects CVD risk.

In conclusion, our meta-analysis confirmed that PO consumption has no negative effect on TC, LDL-c and TG concentrations. In addition, PO consumption results in the elevation of HDL-c concentrations related to CVD relative to the consumption of UFAs. In recent years, PO has emerged as the most cost-effective dietary oil and has thus been widely used by food manufacturers. More robust evidence is required to firmly identify the effects of PO consumption on CVD-related markers. Socioeconomic and environmental data are also required to facilitate the construction of reasonable dietary guidelines, as are ultimate health outcomes.

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AUTHOR DISCLOSURES

None of the authors declared a conflict of interest.

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