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SYSTEMATIC REVIEW

Effects of cocoa products/dark chocolate on serum lipids: a meta-analysis

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Cocoa products, which are rich sources of flavonoids, have been shown to reduce blood pressure and the risk of cardiovascular disease. Dark chocolate contains saturated fat and is a source of dietary calories; consequently, it is important to determine whether consumption of dark chocolate adversely affects the blood lipid profile. The objective was to examine the effects of dark chocolate/cocoa product consumption on the lipid profile using published trials. A detailed literature search was conducted via MEDLINE (from 1966 to May 2010), CENTRAL and ClinicalTrials.gov for randomized controlled clinical trials assessing the effects of flavanol-rich cocoa products or dark chocolate on lipid profile. The primary effect measure was the difference in means of the final measurements between the intervention and control groups. In all, 10 clinical trials consisting of 320 participants were included in the analysis. Treatment duration ranged from 2 to 12 weeks. Intervention with dark chocolate/cocoa products significantly reduced serum low-density lipoprotein (LDL) and total cholesterol (TC) levels (differences in means (95% CI) were −5.90 mg/dl (−10.47, −1.32 mg/dl) and −6.23 mg/dl (−11.60, −0.85 mg/dl), respectively). No statistically significant effects were observed for high-density lipoprotein (HDL) (difference in means (95% CI): −0.76 mg/dl (−3.02 to 1.51 mg/dl)) and triglyceride (TG) (−5.06 mg/dl (−13.45 to 3.32 mg/dl)). These data are consistent with beneficial effects of dark chocolate/cocoa products on total and LDL cholesterol and no major effects on HDL and TG in short-term intervention trials.
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Introduction

Dietary choices are strongly influenced by the taste and texture of foods. Fats are to a large extent responsible for the sensory properties of many foods and, thereby, greatly contribute to eating pleasure. Consumption of foods rich in saturated fatty acids and cholesterol, however, has long been recognized as an important precursor for the development of coronary heart disease. Intake of saturated fatty acids and cholesterol is associated with elevated cholesterol and low-density lipoprotein (LDL) concentrations in the blood (NCEP, 1993; Judd *et al.*, 1994; Temme *et al.*, 1996; Hunter *et al.*, 2010).

Chocolate and cocoa are produced from cacao beans, the seed of *Theobroma cacao*, and are known to contain fats (the dry weight of whole cacao beans is composed of 50–57% lipid, often called cocoa butter (Hannum and Erdman, 2000)). This cocoa butter, predominantly found in dark chocolate, is composed on average of 33% oleic acid, 25% palmitic acid, and 33% of stearic acid. (http://www.nal.usda.gov/fnic/foodcomp/search/), the latter two being saturated fats. Cocoa products are also very rich in plant phytochemicals, especially flavonoids, which are now objects of increased scientific attention due to their potential health benefits (Engler *et al.*, 2004; Grassi *et al.*, 2005a; Wang-Polagruto *et al.*, 2006; Almoosawi *et al.*, 2010).

Previous studies have suggested that dark chocolate consumption reduces blood pressure (Grassi *et al.*, 2005b; Grassi *et al.*, 2008), improves insulin sensitivity as shown by significantly higher QUICKI (quantitative insulin sensitivity check index) measurements (Grassi *et al.*, 2008), improves vascular endothelial function and reverses vascular dysfunction (Engler *et al.*, 2004; Grassi *et al.*, 2005b; Wang-Polagruto *et al.*, 2006), reduces insulin resistance as evidenced by significantly lower HOMA-IR (homeostasis model assessment of insulin resistance) (Grassi *et al.*, 2005a)

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measurements, and increases serum total antioxidant capacity (Wan *et al*., 2001).

Despite solid evidence on the beneficial effects of dark chocolate on blood pressure, limited data exist on the effects of dark chocolate on blood lipids. One clinical trial indicated that regular ingestion of dark chocolate may have no adverse effects on serum lipid profile (Crews *et al*., 2008), whereas others have suggested that intake of dark chocolate reduced serum LDL cholesterol and triglyceride (TG) levels (Engler *et al*., 2004; Grassi *et al*., 2005b), and increased serum high-density lipoprotein (HDL) cholesterol measurements (Mursu *et al*., 2004). An earlier meta-analysis of eight randomized trials involving 215 subjects reported that an intervention with dark chocolate was associated with a significant reduction in serum LDL in subjects with cardiovascular disease risk factors (Jia *et al*., 2010) compared with placebo. However, that meta-analysis did not assess the effect of dark chocolate or cocoa on serum TG concentrations and it did not include some important recent studies.

Dark chocolate is a food consumed frequently and widely all over the world. It is therefore relevant to understand its net benefits on health in order to help the public make informed choices. Hence, we sought to review current evidence on the effects of dark chocolate/cocoa products consumption on serum LDL, HDL and TGs using completed randomized trials.

Materials and methods

Search strategy and study selection

We searched MEDLINE (1966 to May 2010), CENTRAL (The Cochrane Controlled Clinical Trials Register) and the ClinicalTrials.gov website to identify randomized controlled trials examining the effect of dark chocolate or cocoa-containing beverages on blood lipid profile. Our search was restricted to papers published in the English language. For MEDLINE search, we used the MeSH (major subject heading) term 'cacao' or the text words 'cacao', 'flavonoids' or 'chocolate'; 'cholesterol, LDL'; 'cholesterol, HDL'; and 'TGs, cholesterol'. The search was limited to the criteria 'clinical trials', 'English' and 'human'. CENTRAL and the ClinicalTrials.gov website were searched using 'chocolate, cocoa or cacao' as free terms without further restrictions applied to the search. Inspection of the reference list of all identified articles was also conducted. The latter method was repeated until all potentially relevant articles from these sources were identified. Retrieved studies were included if they met the following criteria: (a) were investigating flavanol-rich cocoa products; (b) had a randomized controlled parallel-arm or crossover design; (c) included at least 14 subjects, 18 years and older; and (d) reported 'baseline' and 'end of intervention' mean and standard deviation values of lipid measurements for the active (intervention) and control groups.

Unpublished materials and conference abstracts were excluded from the review as they lacked the necessary detail needed for data synthesis. Single-dose trials were also not included in the analysis because we wanted to report the effects of habitual intake of flavanol-containing cocoa products. Care was taken not to include data from multiple publications of the same population. Furthermore, we excluded studies in which cocoa intake was mixed with other dietary treatments.

Data extraction and quality assessment

Data were extracted by the lead author. Extracted data included the study characteristics (first author's name; year of publication; number and age range of participants; study design; polyphenol amounts in the active and control arms; duration of study; health characteristics of the study population; and location of the study). We also extracted information on the baseline and final concentrations (or net changes) of serum total cholesterol (TC), LDL cholesterol, HDL cholesterol, and TGs. Lead and senior authors all agreed on the eligibility criteria of included studies.

Quality of the studies was evaluated using the validated Jadad score instrument (Jadad *et al*., 1996) with criteria that include: randomization, adequacy of sequence generation, double blinding, and description of drop-outs. The maximum possible score was 5.

Data synthesis and statistical analysis

The effect size used in this investigation was the 'difference in means' between the two treatment groups. We utilized serum cholesterol concentration obtained at the end of each intervention. Studies that reported results in mmol/l were converted to mg/dl using the standard conversion factors (which was a division of the mmol/l value by 0.02586 for TC, LDL and HDL; and by 0.01129 for TG). Standard errors were also converted to standard deviations where necessary. There was a wide variation in the pattern by which the included studies reported their findings.

One trial presented the means and standard deviation of 'baseline' and 'end of treatment' values of the two study groups, as well as the change from baseline (with standard deviations) in the two groups (Crews *et al*., 2008). Another reported the means and standard deviation of the 'baseline' and 'end of treatment' values of the different intervention groups, as well as the 'difference of differences' between the two intervention groups (Muniyappa *et al*., 2008). Some studies reported only mean values (with standard deviation/errors) of 'baseline' and 'end of treatment' values of the intervention groups (Wan *et al*., 2001; Engler *et al*., 2004; Fraga *et al*., 2005; Grassi *et al*., 2005a, b; Balzer *et al*., 2008; Almoosawi *et al*., 2010); One study presented only the 'difference from baseline' in both intervention groups with their standard deviations (Davison *et al*., 2008). For studies that reported only the values of baseline and end of treatment values, the difference was calculated by direct

subtraction of the means, and the standard deviation was calculated using the following formula:

$$\mathrm{SD(difference)} = (\mathrm{SD}^2(\mathrm{cocoa}) + \mathrm{SD}^2(\mathrm{control}) - [2 \times R \times \mathrm{SD(cocoa)} \times \mathrm{SD(control)}])^{1/2},$$

where R is the correlation coefficient calculated from the study that contained all the required values (see above), according to the Cochrane Handbook (http://www.cochrane-handbook.org/) for Systematic Reviews of Interventions (Julian PT Higgins and Sally Green, 2009). Given that only one study provided the means (and standard deviation) of 'baseline' and 'end of treatment' values for the two intervention groups as well as the 'difference of differences' between the groups, we were reluctant to impute the unreported variance for the remaining nine studies by the correlation coefficient method, as this intrinsically assumes that treatment has no effect on the values of the variance. The effect measure was therefore computed as the difference in the postintervention values of serum TC, HDL, LDL and TGs between the active arm and control groups, following dark chocolate or cocoa intake. Additional analyses were performed according to the Cochrane Handbook for Systematic Reviews of Interventions (Higgins and Green, 2009).

Heterogeneity across studies was assessed by the Cochrane *Q*test, and $P<0.10$ was considered statistically significant for heterogeneity. The magnitude of heterogeneity was evaluated by the I^2 statistic (percentage of the variability in effect estimates that is due to heterogeneity rather than sampling error). Whenever the test for heterogeneity was statistically significant, the estimate of the difference was calculated using the random effects model, according to DerSimonian and Laird (1986). Data synthesis and statistical analyses were completed using Cochrane Collaboration Review Manager (RevMan software version 5.0; Cochrane Collaboration, Oxford, UK) (http://www.cc-ims.net/revman) and Microsoft Office Excel 2003 package (Microsoft Corporation, USA).

Results

Most of the studies (1491) produced by our initial search were dropped because their topics were clearly irrelevant to the current project. A total of 20 articles met our inclusion criteria and their full texts were reviewed. Four studies were dropped because flavanol was part of a mixed dietary test regimen (Kris-Etherton *et al*., 1993; Mustad *et al*., 1993; Allen *et al*., 2008) or due to lack of randomization (Baba *et al*., 2007). Five studies were not included because they did not report sufficient details on blood lipid measurements (Kris-Etherton and Mustad, 1994; Polagruto *et al*., 2006; Wang-Polagruto *et al*., 2006; Taubert *et al*., 2007; Grassi *et al*., 2008). One study was excluded because of the lack of a control group (Hamed *et al*., 2008). Another was excluded because it was comparing a milk chocolate intervention with a high carbohydrate diet (Kris-Etherton *et al*., 1994). A flow chart depicting our selection process is shown in Figure 1. The article (Taubert *et al*., 2007) was excluded because it did not report (or provide on request) the end-of-intervention values for LDL, HDL and TG measurements.

In all, 10 articles were included in our analyses with a total of 320 individuals. Characteristics of the included studies are presented in Table 1. The duration of the intervention ranged from 2 to 12 weeks. Five of the studies were conducted on healthy subjects; two each were carried out on hypertensive and obese subjects. The last study involved diabetic patients on hypoglycemic agents.

The mean age was 41.7 years (range 21–80 years). Eight of the studies were comparing flavanol-rich cocoa or dark chocolate with either flavanol-poor white chocolate or a matching placebo.

All the included studies were randomized and controlled (parallel arm or crossover). Five were double blind (Engler *et al*., 2004; Balzer *et al*., 2008; Crews *et al*., 2008; Davison *et al*., 2008; Muniyappa *et al*., 2008) and only one study (Balzer *et al*., 2008) described an adequate method of sequence generation. Seven studies reported details of dropouts and withdrawals (Engler *et al*., 2004; Grassi *et al*., 2005a; Balzer *et al*., 2008; Crews *et al*., 2008; Davison *et al*., 2008; Muniyappa *et al*., 2008; Almoosawi *et al*., 2010). Overall, five of the studies obtained a Jadad score of $\geqslant 3$ (high quality) (Table 1).

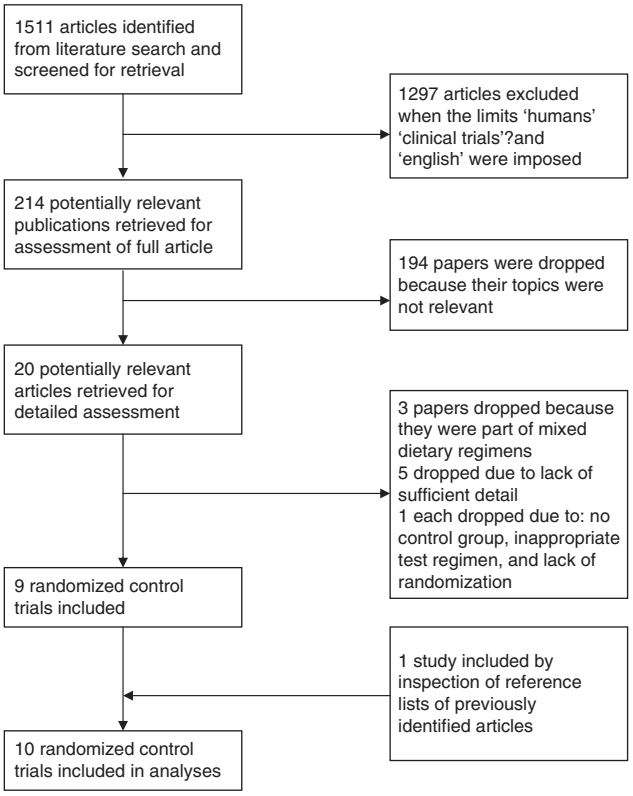

Figure 1 Flow diagram of study selection process.

Table 1 Characteristics of included studies

Study	*Intervention*	*Control*	*Flavanol intake (active arm)*	*Flavanol intake (control)*	*Design*	*Jadad score—quality ranking (0–5)*	*Duration*	*Population characteristics*	*Number of subjects*	*Age range (years)*	*Location*
Almoosawi *et al.* (2010)	20 g dark chocolate	20 g dark chocolate	1000 mg polyphenol	500 mg polyphenol	Randomized crossover	2	2 weeks	Healthy overweight and obese	14	21–50	UK
Balzer *et al.* (2008)	Cocoa drink	Placebo	963 mg flavanol	75 mg flavanol	Randomized parallel group	5	30 days	Medicated diabetic patients	41	50–80	Germany
Muniyappa *et al.* (2008)	31 g cocoa drink	Placebo	900 mg flavanol	28 mg flavanol	Randomized placebo-controlled crossover	4	2 weeks	Mild-to-moderate hypertensive without medication	20	51 ± 1.5	Bethesda, MD, USA
Crews *et al.* (2008)	37 g dark chocolate bar and cocoa beverage	Placebo	754.71 mg proanthocyanin	0.20 mg/g proanthocyanin of chocolate bar; 40.87 mg/g of cocoa beverage	Randomized placebo-controlled parallel group	4	6 weeks	Healthy older adults	90	⩾60	VA, USA
Davison *et al.* (2008)	Cocoa mix	Placebo	902 mg flavanol	36 mg flavanol	Randomized placebo-controlled parallel group	4	12 weeks	Overweight and obese	49	18–65	Australia
Grassi *et al.* (2005a, b)	100 g dark chocolate	90 g white chocolate	88 mg flavanol	0 mg flavanol	Randomized crossover	1	15 days	Grade I essential hypertension	20	25–60	Italy
Fraga *et al.* (2005)	105 g milk chocolate	Cocoa butter	168 mg flavanol	5 mg flavanol	Randomized crossover	1	14 days	Healthy males	27	18–20	Argentina
Grassi *et al.* (2005a, b)	100 g dark chocolate	90 g white chocolate	88 mg flavanol	0 mg flavanol	Randomized crossover	2	15 days	Healthy	15	33.9 ± 7.6	Italy
Engler *et al.* (2004)	46 g dark chocolate	46 g low-flavanol dark chocolate	213 mg procyanidins	Trace	Randomized, placebo-controlled parallel group	4	2 weeks	Healthy	21	21–55	CA, USA
Wan *et al.* (2001)	Average American diet supplemented with 16 g dark chocolate and 22 g cocoa powder	Average American diet controlled for fiber, caffeine and theobromine	466 mg procyanidins	Trace	Randomized crossover	1	4 weeks	Healthy	23	21–62	PA, USA

The postintervention difference in mean LDL concentration (95% CI) comparing active treatment with placebo was −5.90 mg/dl (−10.47, −1.32 mg/dl) (Figure 2). Corresponding differences for HDL, TG and TC were −0.76 mg/dl (−3.03, 1.51 mg/dl) (Figure 3), −5.06 mg/dl (−13.45, 3.32 mg/dl) (Figure 4) and −6.23 mg/dl (−11.60, −0.85 mg/dl), respectively. There was evidence for heterogeneity for LDL ($I^2 = 32\%$) and TC ($I^2 = 24\%$), but not for HDL or TG (I^2 of 0% each).

Subgroup analysis was carried out with the data segregated by study duration, study design, flavanol dose, location and health status of participants (Table 2). Trials of short duration (about 2 weeks) showed a significant reduction in serum LDL (−8.44 mg/dl, −14.23 to −2.64 mg/dl), but a nonsignificant reduction in serum HDL and TG levels (Table 2). Studies with longer duration (4–12 weeks) showed a nonsignificant reduction in LDL, HDL and TG levels. The subgroup analyses by study design showed nonsignificant reductions in LDL and HDL serum levels, howbeit, the crossover studies provided narrower interval estimates (than those of the parallel-arm design). Though the formulation of the administered cocoa varied among the studies, the investigators largely reported the flavanol content of their intervention, hence, we also examined a possible dose-effect relationship. Five of the studies administered daily flavanol doses of less than 500 mg; the others administered 500 mg or more. None of the results was statistically significant, but daily flavanol doses of less than 500 mg seemed to produce more marked reduction in LDL concentrations. Subgroup analyses by health status also produced nonsignificant findings, though greater reductions in LDL and TG concentrations were recorded in participants with documented cardiovascular disease risk factors. Analysis by location in which study was carried out revealed a significant reduction in serum LDL concentration −7.13 mg/dl (−14.26, −0.00 mg/dl) for the trials carried out in Europe, others were not significant (Table 2).

Sensitivity analysis that excluded the lower quality studies showed that habitual cocoa intake did not significantly reduce serum lipid concentration (Table 2). When we excluded the two studies (Wan *et al*., 2001; Fraga *et al*., 2005) that did not compare flavanol-rich cocoa (or dark chocolate) with flavanol-poor white chocolate (or a matching placebo), we observed a significant reduction in LDL concentration (Table 2).

Discussion

Our analyses showed a statistically significant reduction in LDL and TC after intervention with dark chocolate/cocoa products. There was also a nonsignificant reduction in serum TG and HDL cholesterol with ingestion of dark chocolate/cocoa products when compared with placebo. The dark chocolate/cocoa effect seemed stronger in subjects with higher risk of cardiovascular disease and in studies with a relatively shorter duration.

This observed reduction may be attributable to flavonoids contained in cocoa and dark chocolate. Flavan-3-ols in cocoa are present as monomers, oligomers or polymers, better known as procyanidins, and generally are thought to inhibit cholesterol absorption as well as the expression of LDL cholesterol receptors (Matsui *et al*., 2005). The degree to which LDL and TC levels were reduced in this analysis reflects some measure of potency of the cocoa regimen. Our results are consistent with a similar review (Jia *et al*., 2010) conducted on eight studies, which reported that intervention with dark chocolate/cocoa products led to LDL reduction by 5.87 mg/dl (−11.13, −0.61 mg/dl) and TC reduction by 5.82 mg/dl (95% CI: −12.39, 0.76 mg/dl) compared with placebo. In addition, we are reporting a nonsignificant reduction in mean serum TG levels by 5.06 mg/dl (95% CI: −13.45, 3.32 mg/dl).

The obvious challenge of blinding (when it comes to chocolate products) has been raised as a possible reason why results are not entirely consistent among individual studies.

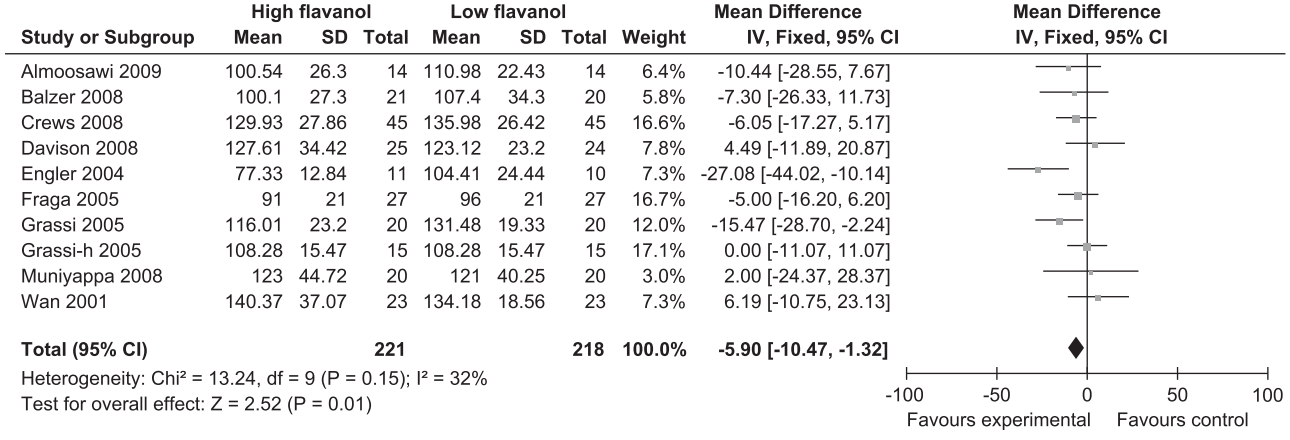

Figure 2 Meta-analysis of the effect of chocolate/cocoa consumption on LDL cholesterol. The sizes of the data markers indicate the weight of each study in the analysis. IV, inverse variance; fixed, fixed effects model. Values are in mg/dl.

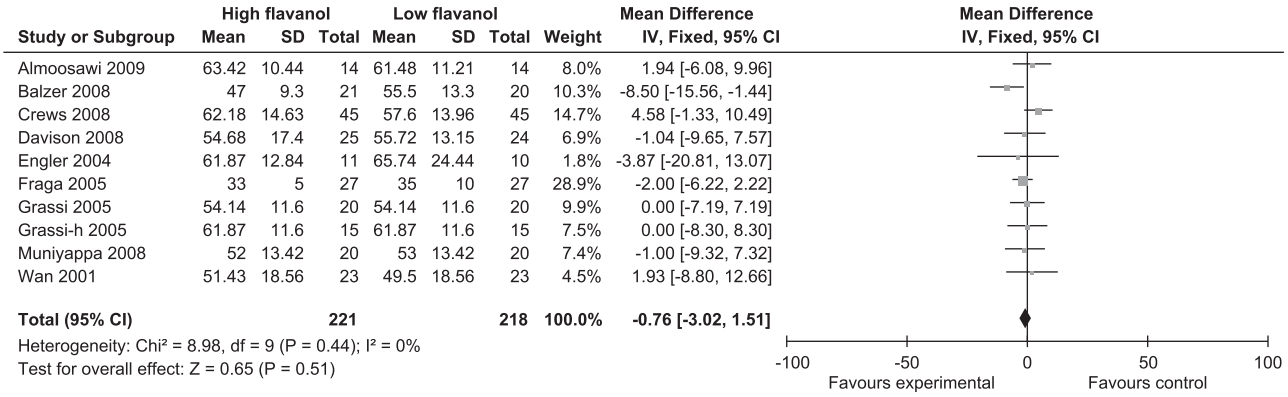

Figure 3 Meta-analysis of the effect of chocolate/cocoa consumption on HDL cholesterol. The sizes of the data markers indicate the weight of each study in the analysis. IV, inverse variance; fixed, fixed effects model. Values are in mg/dl.

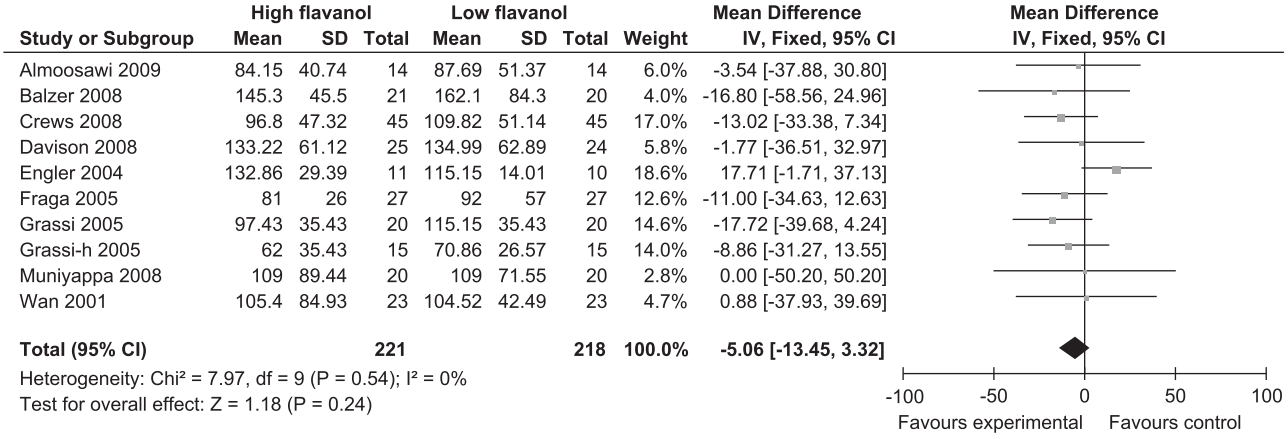

Figure 4 Meta-analysis of the effect of chocolate/cocoa consumption on serum TG. The sizes of the data markers indicate the weight of each study in the analysis. IV, inverse variance; fixed, fixed effects model. Values are in mg/dl.

However, when we excluded studies that compared dark chocolate with white chocolate (or in which participants were not properly blinded), our findings were essentially unchanged. It also did not matter whether the study design utilized a crossover or parallel-arm control group, as the results were similar, though the studies that made use of a parallel-arm design exhibited more heterogeneity.

The daily dose of flavanol consumption by the active arm groups in the included studies ranged from 88 to 963 mg. Typical US daily intakes of flavanol are on the order of 20–100 mg (Mink *et al*., 2007). This raises questions about the usefulness of the information provided by these studies. Consequently, we conducted a subgroup analyses (by dose) that showed a greater reduction in serum LDL concentrations in those studies that administered less than 500 mg of flavanol daily (compared with those that administered $\geqslant$500 mg), though this reduction wasn't significant. Studies are needed that will provide insight on the optimal daily dose range of flavanol consumption.

Recently, it has been proposed that there may be a discrepancy in the effective dose of flavanols when delivered in a chocolate matrix compared with a beverage mix. A bioavailability study however refutes this, showing that there was no difference in the acute increases in plasma or urinary concentrations of flavanols after consumption of chocolate or dry cocoa containing the same quantities of flavanols (Baba *et al*., 2000). Nevertheless, when our analyses were restricted to those studies that strictly utilized dark chocolate in the active arm rather than cocoa beverages (Engler *et al*., 2004; Grassi *et al*., 2005a; Grassi *et al*., 2005b; Balzer *et al*., 2008; Almoosawi *et al*., 2010), we observed a stronger reduction in serum LDL concentration (−11.31 mg/dl; 95% CI was −20.79 to −1.83 mg/dl).

Further analyses by duration of intake revealed that dark chocolate or cocoa intake has a more meaningful effect on LDL cholesterol levels during a short-term than over a long-term intervention. A possible reason for this may be the fall in compliance that is often associated with studies that go on for a longer duration.

A number of limitations in these analyses merit some comments. There was a wide variation in the amount and formulation of cocoa product used. Many of the studies used

Table 2 Further analyses of serum LDL, HDL cholesterol and triglycerides by different variables (mg/dl)

Variables	*LDL cholesterol*			*HDL cholesterol*		*Triglycerides*	
	Number of trials	*Mean difference (95% CI)*	P-*value for heterogeneity*	*Mean difference (95% CI)*	P-*value*	*Mean difference (95% CI)*	P-*value for heterogeneity*
Duration							
Short (2 weeks)	6	−8.44 (−14.23, −2.64)*	0.11	−0.89 (−3.74, 1.95)	0.97	−3.09 (−13.21, 7.04)	0.23
Medium (4–12 weeks)	4	−1.67 (−9.14, 5.80)	0.51	−0.81 (−7.20, 5.58)	0.05	−9.36 (−24.30, 5.58)	0.87
Design							
Crossover	6	−4.55 (−10.34, 1.24)	0.36	−0.62 (−3.41, 2.17)	0.96	−9.85 (−21.20, 1.50)	0.96
Parallel arm	4	−8.69 (−20.78, 3.40)	0.07	−1.75 (−8.65, 5.14)	0.05	0.69 (−11.75, 13.12)	0.15
Dose							
Flavanol ⩾500 mg	5	−4.25 (−11.52, 3.02)	0.74	−0.67 (−5.45, 4.11)	0.78	−9.00 (−23.06, 5.06)	0.95
Flavanol <500 mg	5	−7.82 (−17.83, 2.19)	0.03	−1.07 (−4.19, 2.06)	0.95	−2.89 (−13.33, 7.55)	0.14
Location							
USA	4	−6.95 (−20.92, 7.01)	0.04	2.17 (−2.08, 6.42)	0.64	2.63 (−10.14, 15.41)	0.20
Europe	4	−7.13 (−14.26, −0.00)*	0.36	−2.02 (−5.82, 1.77)	0.19	−12.22 (−25.72, 1.28)	0.89
Health status							
Healthy	5	−5.77 (−14.53, 2.99)	0.06	0.20 (−2.80, 3.19)	0.48	−2.23 (−12.48, 8.02)	0.20
CVD risk factors	5	−7.23 (−14.97, 0.51)	0.40	−2.04 (−5.51, 1.43)	0.33	−10.77 (−25.33, 3.78)	0.90
Sensitivity Analyses							
High quality (Jadad >3)	5	−7.39 (−17.99, 3.20)	0.10	−1.49 (−6.75, 3.76)	0.10	0.65 (−11.42, 12.72)	0.25
Excluding Wan *et al*. (2001) and Fraga *et al*. (2005)	8	−5.90 (−10.47, −1.32)*	0.15	−0.76 (−3.02, 1.51)	0.44	−4.50 (−13.71, 4.72)	0.37

Abbreviations: CI, confidence interval; CVD, cardiovascular disease; HDL, high-density cholesterol; LDL, low-density cholesterol.
*Indicates a significant result.

quantities of cocoa that may be impractical to recommend for long-term daily consumption (mostly >30 g). In addition, the control diet regimen varied remarkably across studies; this may have contributed to some of the heterogeneity found in the results (I^2 statistic was 32% for LDL and 24% for TC) (Figures 2 and 4). Half of the trials included were judged to be of low quality (Jadad score <3). This is largely due to the lack of adequate blinding of subjects and investigators and may have led to some bias. Our review is further limited by the relatively small number of available trials and subjects studied. The generalizability of our study is limited as most of the studies were carried out on healthy subjects. Treatment duration was relatively short; hence, we cannot predict the effects of habitual cocoa intake on lipids over several months to years.

Our analysis however has some strengths. First, most of our results showed relatively very little or no heterogeneity. Second, as with many meta-analyses, by combining information from all relevant studies, we provide more precise and powerful estimates of the effect measure than those derived from the individual studies. Third, we included only randomized controlled trials that followed rigorous protocols and thereby minimized bias.

In conclusion, these current analyses are consistent with beneficial effects of dark chocolate/cocoa product consumption on LDL and neutral effects on TG and HDL in a short-term intervention. Dark chocolate also appears to be a more effective matrix for delivering flavanols than cocoa beverages. Additional studies to evaluate the optimal dose of cocoa consumption and long-term effects of dark chocolate on serum lipids are needed to help appraise the net benefit of dark chocolate consumption on health.

Conflict of interest

The authors declare no conflict of interest.

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