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Effects of olive oil on blood pressure: A systematic review and meta-analysis

F. Zamora-Zamora[a,✉], J.M. Martínez-Galiano[b,c], J.J. Gaforio[c,d,e,f] and M. Delgado-Rodríguez[b,c]

[a]Paediatric Emergency Department, Hospital Complex of Jaén. Av. del Ejército Español 10; 23007 Jaén, Spain
[b]Department of Health Sciences, Faculty of Experimental Sciences, University of Jaén, Campus las Lagunillas s/n; 23071 Jaén, Spain
[c]CIBER-ESP, Instituto de Salud Carlos III, C/ Monforte de Lemos 3-5, Pabellón 11, Planta 0, 28029 Madrid, Spain
[d]Center for Advanced Studies in Olive Grove and Olive Oils. University of Jaén, Spain
[e]Immunology Division, Department of Health Sciences, Faculty of Experimental Sciences, University of Jaén, Campus las Lagunillas s/n; 23071 Jaén, Spain
[f]Agrifood Campus of International Excellence, ceiA3, Spain

✉Corresponding author: francisca.zamora.sspa@juntadeandalucia.es

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SUMMARY: Hypertension is one of the most important risk factors associated with the development of cardiovascular diseases. Numerous studies have revealed that a diet enriched in olive oil can have a beneficial effect on blood pressure. This systematic review includes the effects of olive oil on blood pressure in individuals without previous cardiovascular events. Liquid oil shows a decrease in blood pressure, while capsules have not produced any effect. Diastolic blood pressure decreased after the consumption of olive oil, -0.73 mm Hg, 95% CI (-1.07, -0.40); $p < 0.001$, $I^2 = 86.9\%$, with high heterogeneity among the included studies. This reduction was mainly due to extra virgin olive oil (EVOO) from 10 ml to 50 ml/day: -1.44 mm Hg, 95% CI (-1.89, -1.00); $p < 0.001$. Regarding systolic blood pressure the observed decrease is not statistically significant. Further studies on the consumption of EVOO are needed to confirm these results.

KEYWORDS*: Diastolic Pressure; Hypertension; Olive oil; Randomized Controlled Trial; Systematic review; Systolic pressure*

RESUMEN: ***Efectos del aceite de oliva en la presión arterial: revisión sistemática y metaanálisis****.* La hipertensión es uno de los factores de riesgo más importantes asociados con al desarrollo de enfermedades cardiovasculares. Numerosos estudios han revelado que una dieta enriquecida en aceite de oliva puede producir un efecto beneficioso sobre la tensión arterial. En esta revisión sistemática se recogen los efectos del aceite de oliva sobre la tensión arterial en individuos sin eventos cardiovasculares previos. Es el aceite líquido el que ha mostrado los beneficios, mientras que las cápsulas no han producido ningún efecto. La tensión arterial diastólica disminuyó después del consumo de aceite de oliva, -0.73 mm Hg, IC 95% (-1.07, -0.40); $p < 0.001$, $I^2 = 86.9\%$, con elevada heterogeneidad entre los estudios incluidos. Esta reducción se debió principalmente al aceite de oliva virgen extra (AOVE) de 10 ml a 50 ml / día: -1.44 mm Hg, IC 95% (-1.89, -1.00); $p < 0.001$. En lo que se refiere a la tensión arterial sistólica el descenso producido no ha sido estadísticamente significativo. Se necesitan más estudios sobre el consumo de AOVE para confirmar estos resultados.

PALABRAS CLAVE*: Aceite de oliva; Ensayo controlado aleatorizado; Hipertensión; Presión diastólica; Presión sistólica; Revisión sistemática*

ORCID ID: Zamora-Zamora F https://orcid.org/0000-0002-2623-8645, Martínez-Galiano JM https://orcid.org/0000-0002-0878-8635, Gaforio JJ https://orcid.org/0000-0003-2996-9301, Delgado–Rodríguez M https://orcid.org/0000-0002-3838-2548

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1. INTRODUCTION

Hypertension is one of the most important risk factors associated with the development of cardiovascular disease. The threshold for the diagnosis of hypertension is a systolic blood pressure (SBP) of at least 140 mm Hg, a diastolic blood pressure (DBP) of at least 90 mm Hg, or both (Poulter *et al*., 2015). Hypertension increases the risk of stroke, coronary heart disease, sudden death, heart failure and peripheral arterial disease (Mancia *et al*., 2013). A change in lifestyle can be an effective intervention to control blood pressure. The preventive measures to adopt are restriction of salt in the diet, moderation in alcohol consumption, abundant fruit consumption, control of weight, regular physical activity, and smoking cessation (Dickinson *et al*., 2006).

Several epidemiological studies have analyzed the relationship between monounsaturated fatty acid (MUFA) consumption, such as olive oil, and hypertension (Alonso *et al*., 2006). In 2005, the OmniHeart study compared three diets: one rich in carbohydrates, another rich in vegetable proteins, and the third with MUFA. The diets rich in vegetable proteins and MUFA compared with the carbohydrate diet reduced blood pressure and improved the lipid profile (Appel *et al*., 2005). The International Study of Macro/Micronutrients and Blood Pressure (INTERMAP) is a multicenter cross-sectional study of 4680 men and women in which linear regression analyses showed a significant inverse relationship between total MUFA intake and DBP. A Spanish study showed that the consumption of vegetable oleic acid, with a daily intake of 13 g/day, was associated with a decrease in SBP (-0.70 mmHg) and DBP (-0.57mm Hg) (Miura *et al.,* 2013). In the PREDIMED (Prevención con Dieta Mediterránea) clinical trial both SBP and DBP decreased 2.3 and 1.2 mm Hg, respectively, after one year of follow-up (Doménech *et al*., 2014).

The consumption of olive oil is very common in Mediterranean countries. It is associated with the Mediterranean diet and it is not clear whether the effects of olive oil are due to the oil itself or to the whole diet pattern. The objective of this study is to assess whether the consumption of olive oil reduces blood pressure in adults without previous cardiovascular events.

2. METHODS

2.1. Design

We carried out a systematic review and meta-analysis following the recommendations established by the PRISMA statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyzes) (Moher *et al*., 2009). A systematic review protocol was developed, not registered a priori, and not modified after the beginning of the review process.

2.2. Eligibility criteria

We used the following inclusion criteria: a) participants: adult population with at least 18 years of age without previous cardiovascular events; b) intervention: diet enriched with olive oil for at least 12 weeks vs. diet enriched with other fat; c) outcome measures: SBP or DBP; d) design of included studies: randomized controlled trials (RCTs). We have included both healthy individuals with cardiovascular risk factors or with other non-cardiovascular pathology.

2.3. Exclusion criteria

We exclude studies in which the intervention was carried out in cardiovascular patients because they experience a profound change in their lifestyle, including diet, not comparable with healthy subjects or with other types of diseases. Animal studies were discarded.

2.4. Research methods

The following electronic databases were searched from their inception through April 10, 2018: PubMed, Embase, Cochrane plus, Web of Science, Ovid, Scopus, VHL, TDR. The language of publication was not restricted.

The search strategy was carried out through the combination of keywords related to olive oil intake (olive oil), and the different expected results: hypertension (arterial pressure, hypertension, blood pressure, DBP, SBP), and the design of adequate studies for inclusion (randomized controlled trial, systematic review, meta-analysis). Reference lists of identified original articles were searched manually. Table 1 shows the search strategy for the databases.

TABLE 1. Search strategy

PubMed, Web of Science, Embase, Ovid, Biblioteca Cochrane plus, Scopus, VHL, TDR
1. olive oil
2. Arterial Pressure
3. Hypertension
4. Blood Pressure
5. Diastolic Pressure
6. Systolic Pressure
7. 2# OR 3# OR 4# OR 5# OR 6#
8. 1# AND 7#
9. 8# AND (Randomized Controlled Trial OR systematic review OR Meta-Analysis)
10. 9# AND humans
VHL
1. olive oil
2. hypertension
3. Humans
4. 1# AND 2# AND 3#

2.5. Risk of bias in individual studies

We used the Cochrane risk of bias tool to assess risk of bias within the following domains: selection bias, performance bias, detection bias, attrition bias, reporting bias, and other bias (Higgins and Green, 2011). Table 2 shows the studies after the validity analysis.

2.6. Data extraction and management

Two researchers made the selection of articles independently. Discrepancies were discussed with a third review author until consensus was reached. The following data were extracted from each study: authors, year of publication, country of implementation, duration, amount of olive oil intake in the experimental group and fat in the control one, characteristics and number of participants in each intervention applied, SBP and DBP (Table 2).

2.7. Data synthesis

The outcome parameter was the change in blood pressure regarding baseline values; the mean standard error of the change was computed. Mean differences (MDs) were pooled using a fixed effects model. Heterogeneity between studies results was tested using the Q test. The proportion of heterogeneity was quantified with the I^2 parameter. $I^2 > 50$ % was considered to represent considerable heterogeneity. Metarregression was performed to explore the causes of heterogeneity. We applied Egger's method to determine the possible existence of publication bias. All data were analyzed using Stata 14 SE program (College Station, TX, USA).

3. RESULTS

3.1. Literature research

The search identified 872 studies, 687 of which were identified in different databases: 119 in PubMed, 23 in Embase, 32 in the Cochrane Plus Library, 167 in the Web of Science, 35 in Ovid, 232 in Scopus, and 79 in VHL; while 185 were located through the grey literature of TDR and hand searched for references. After the exclusion of duplicates, 691 studies were evaluated. 27 studies were reviewed in full text, and 15 studies were finally included. The reasons for exclusion are detailed in Figure 1.

3.2. Characteristics of studies included in systematic review

Fifteen studies were included in the systematic review and meta-analysis (Kristensen *et al*., 2016, Rozati *et al*., 2015, Lee *et al*., 2015, Venturini *et al*., 2015, Ceriello *et al*., 2014, Toledo *et al*., 2013, Singhal *et al.*, 2013, Tapsell *et al*., 2013, Konstantinidou *et al.,* 2010, Taylor *et al*., 2006, Rasmussen *et al.,* 2006, Olsen *et al.,* 2000, Ferrara *et al.,* 2000, Prisco *et al.,* 1998, Bonnema *et al.,* 1995). Table 2 shows a summary of the information extracted from the included studies. The designs used by the studies were: double blind parallel RCTs (Kristensen *et al*., 2016, Lee *et al*., 2015, Singhal *et al.*, 2013, Taylor *et al*., 2006, Olsen *et al.,* 2000, Prisco *et al.,* 1998, Bonnema *et al.,* 1995), double-blind, randomized crossover study (Ferrara *et al.,* 2000), and non-blinded RCTs (Rozati *et al*., 2015, Venturini *et al*., 2015, Ceriello *et al*., 2014, Toledo *et al*., 2013, Tapsell *et al*., 2013, Konstantinidou *et al.,* 2010, Rasmussen *et al.,* 2006). The follow-up ranged from 12 weeks to 4 years. The countries in which the studies were developed were Spain (Ceriello *et al*., 2014, Toledo *et al.,* 2013, Konstantinidou *et al.,* 2010), Denmark (Kristensen *et al.* 2016, Bonnema *et al.,*1995), Italy (Ferrara *et al.*, 2000, Prisco *et al.,* 1998), United Kingdom (Singhal *et al.,* 2013, Taylor *et al.,* 2006), South Korea (Lee *et al.,* 2015), USA (Rozati *et al.,* 2015), Brazil (Venturini *et al.,* 2015), Australia (Tapsell *et al.,* 2013), and two multinational studies: Denmark, United Kingdom, Sweden, Italy, Netherlands, Belgium, Russia and Norway (Olsen *et al.,* 2000); and Finland, Denmark, Italy, Australia and Sweden (Rasmussen *et al.,* 2006).

The fifteen studies included 6651 participants: 3358 had ingested olive oil and 3293 were fed the control diet. Four studies had more than two arms; in these studies the following branches were discarded for the present review: in the PREDIMED study the branch with Mediterranean diet plus nuts (Toledo *et al.*, 2013), refined olive oil (Konstantinidou *et al*., 2010), hypocaloric diet plus fish (Tapsell *et al.*, 2013), and pregnant women with fewer weeks of administration (Olsen *et al*., 2000). Venturini *et al*., (2015) gives their outcomes as mean and interquartile range and they could not be included in meta-analysis. Men and women were pooled in the analyses.

The participants were adults without cardiovascular events. Some participants had cardiovascular risk factors such as overweight or obesity (Rozati *et al*., 2015, Tapsell *et al*., 2013, Taylor *et al*., 2006), diabetes mellitus (Ceriello *et al*., 2014), incipient or established diabetic nephropathy (Lee *et al.,* 2015, Bonnema *et al.,* 1995) or more than three cardiovascular risk factors (Toledo *et al.,* 2013), hypertension (Ferrara *et al*., 2000, Prisco *et al*., 1998), metabolic syndrome (Venturini *et al*., 2015) and psoriatic arthritis (Kristensen *et al*., 2016). Three studies were performed in healthy adults (Singhal *et al.,* 2013, Konstantinidou *et al*., 2010, Rasmussen *et al*., 2006). Olsen *et al*., (2000) recruited twin pregnancies and pregnancy induced hypertension.

TABLE 2. Characteristics of studies included in the systematic review

Studies	Country	Design	Duration of intervention	Participants	Treatment group	Control group	Outcomes Treatment group	Outcomes Control group
Kristensen *et al.*, 2016	Denmark	Double-blind RCT	24-week	Psoriatic arthritis	Capsules 3 g olive oil /day N = 60	Capsules 3 g n-3 PUFA / N = 68	SBP decrease DBP decrease	SBP decrease DBP decrease
Rozati *et al.*, 2015	USA	RCT	3 months	Overweight and obese	Extra virgin olive oil 39±7g/ day +American diet N = 20	Corn oil, soybean oil and butter: 41 ± 8 g / day plus American diet N = 21	SBP decrease DBP decrease	SBP without change DBP decrease
Lee *et al.*, 2015	South Korea	Double-blind RCT	12 weeks	Diabetic nephropathy	3 g olive oil / N = 8	Omega-3 FA: 3 g / day / N=11	SBP decrease DBP without change	SBP increase DBP decrease
Venturini *et al.*, 2015	Brazil	RCT	90 days	Metabolic syndrome	10 ml extra virgin olive oil /day N = 13	Usual diet / N = 42	SBP decrease DBP decrease	SBP increase DBP decrease
Ceriello *et al.*, 2014	Spain	RCT	3 months	Diabetics type II	Extra virgin olive oil 50 ml /day /N = 12	Low fat diet/ N = 12	SBP decrease DBP increase	SBP decrease DBP decrease
Toledo *et al.*, 2013	Spain	RCT	4 years	Diabetic or ≥ 3 cardiovascular risk factors	Mediterranean diet + extra virgin olive oil 50 ml /day N = 2441	Low-fat diet / N = 2350	SBP decrease DBP decrease	SBP decrease DBP decrease
Singhal *et al.*, 2013	United Kingdom	Double blind RCT	16 weeks	No diabetics or chronically ill	Capsules 4g / day olive oil / N = 162	4 g (microalgae + palmitic acid) / N = 162	SBP decrease DBP decrease	SBP decrease DBP decrease
Tapsell *et al.*, 2013	Australia	RCT	1 year	Non-diabetic obesity	Hypocaloric diet + 1g olive oil /day N = 37	Hypocaloric diet + fish + DHA and EPA / N = 38	SBP decrease DBP decrease	SBP decrease DBP increase
Konstantinidou *et al.*, 2010	Spain	RCT	3 months	Healthy adults	Mediterranean diet + extra virgin olive oil / N = 30	Habitual diet / N = 29	SBP decrease DBP increase	SBP increase DBP increase
Taylor *et al.*, 2006	United Kingdom	Double-blind RCT	12 weeks	Overweight	Olive oil 54 cal /day Capsules N = 19	Conjugated linoleic acid 4.5 g / d; 60 cal /day Capsules / N = 21	SBP increase DBP decrease	SBP decrease DBP increase
Rasmussen *et al.*, 2006	Finland, Denmark; Italy; Australia; Sweden	RCT	3 months	Healthy adults	Olive oil capsules 3.6g/day + MUFA diet N = 19	Fish oil capsules 3.6g + MUFA diet /N = 21	SBP decrease DBP decrease	SBP decrease DBP decrease
Olsen *et al.*, 2000	Denmark, United Kingdom;Sweden;Italy; Netherlands;Belgium; Russia;Norway	Double-blind RCT	20 weeks	Pregnant	4g Olive oil capsules / day. Group Hypertension induced by pregnancy N = 202 Twin pregnancy group N = 290	4 capsules of fish oil Group Hypertension induced by pregnancy N = 184 Twin pregnancy group N = 289	DBP increase	DBP increase
Ferrara *et al.*, 2000	Italy	Double-blind crossover	1 year	Hypertensive	Extra virgin olive oil 40g Men and 30 g women /day N = 23	Sunflower oil / 40 g men and 30 g women/day N = 23	SBP decrease DBP decrease	SBP increase DBP without change
Prisco *et al.*, 1998	Italy	Double blind RCT	4 months	Hypertensive	4g olive oil / day + Mediterranean diet / N = 8	4gr EPA and DHA/day + Mediterranean diet / N = 8	SBP without change DBP without change	SBP decrease DBP decrease
Bonnema *et al.*, 1995	Denmark	Double-blind RCT	6 months	Diabetics with incipient nephropathy	Olive oil 6 g in capsules / N = 14	6 g in fish oil capsules/ N = 14	SBP increase DBP increase	SBP decrease DBP decrease

Cal/d: calories/day; DBP: diastolic blood pressure; DHA: docosahexaenoic acid; EPA: eicosapentaenoic acid; FA: fatty acid; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; RCT: randomized controlled trial; SBP: systolic blood pressure.

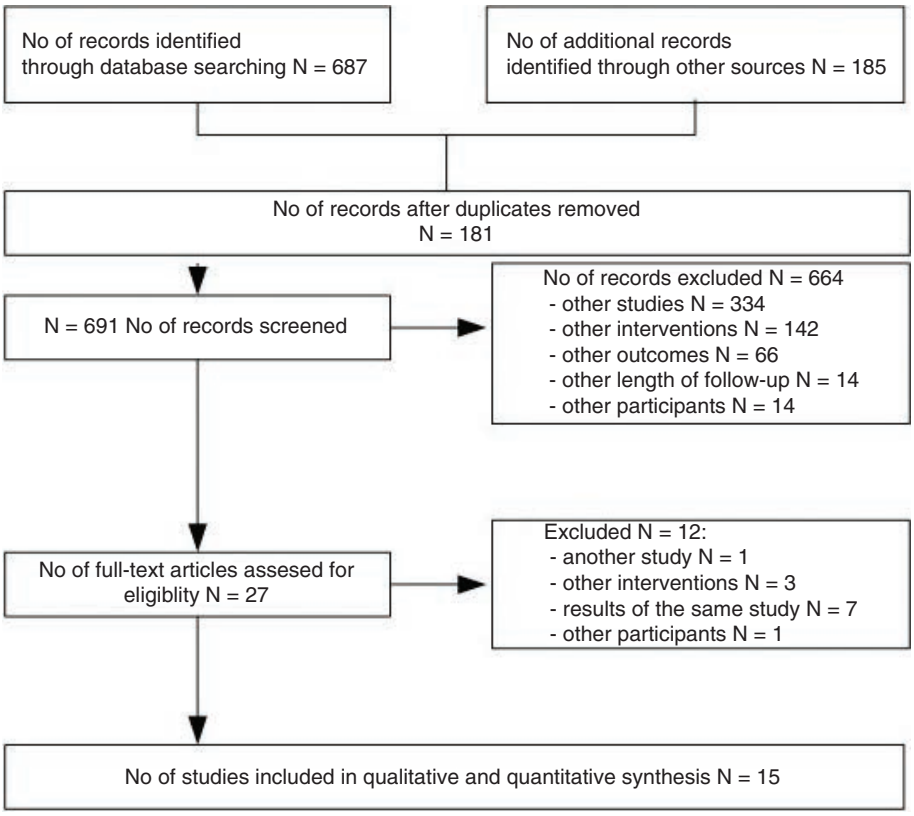

FIGURE 1. Flow chart of study procedure. Randomized controlled studies of at least three months duration, not developed in animals, or in individuals with previous cardiovascular events have been included. Other interventions have been excluded, such as the administration of other non-ingested supplements or the intake of two oils together at the same time.

3.3. Types of interventions

The olive oil was administered in capsules of 1-6 g/day (Kristensen *et al*., 2016, Lee *et al*., 2015, Singhal *et al*., 2013, Tapsell *et al.*, 2013, Taylor *et al*., 2006, Rasmussen *et al.,* 2006, Olsen *et al*., 2000, Prisco *et al.*, 1998, Bonnema *et al.,* 1995), and in liquid form as extra virgin olive oil (EVOO) from 10 ml to 50 ml/day (Rozati *et al*., 2015, Venturini *et al*., 2015, Ceriello *et al*., 2014, Toledo *et al*., 2013, Ferrara *et al.,* 2000, Konstantinidou *et al.,* 2010), in the context of different types of diets, such as the American diet (Rozati *et al.,* 2015), or the Mediterranean diet (Konstantinidou *et al*., 2010, Toledo *et al*., 2013, Prisco *et al*., 1998). The studies that supplemented liquid oil provided it as EVOO, while the studies with capsule supplement provided it with olive oil.

The control groups took both capsules, liquid oil, habitual diet and low-fat diet. The controls took capsules with different fatty acids: microalgae and palmitic acid (Singhal *et al.,* 2013), conjugated linoleic acid (Taylor *et al*., 2006), docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) (Kristensen *et al*., 2016, Lee *et al.*, 2015, Tapsell *et al*., 2013, Bonnema *et al.*, 1995, Rasmussen *et al*., 2006, Olsen *et al*., 2000, Prisco *et al*., 1998). In liquid form the next fats were administered to the control groups: corn oil, soybean oil and butter (Rozati *et al.*, 2015), and sunflower oil (Ferrara *et al.*, 2000). Finally, in four studies, no supplement was provided to the control groups: habitual diet (Venturini *et al.,* 2015, Konstantinidou *et al.,* 2010), and low fat diet (Ceriello *et al.,* 2014, Toledo *et al.,* 2013).

The diet administered was adequate to the energy requirements, except in Tapsell *et al*., (2013) who administered a hypocaloric diet with 1750 (SD 417) kcal and 1600 (SD 355) kcal in the olive oil and control groups, respectively. Physical activity was not restricted in the included studies; they were requested to maintain their regular routine of physical activity. Tapsell *et al*., (2013), recommended walking for 30-minutes three days a week, with similar results among groups.

3.4. Outcome measures

Fourteen studies assessed DBP and SBP, and one study only DBP (Olsen *et al*., 2000). No adverse events were mentioned: only nine participants in the n-3 polyunsaturated fatty acid (PUFA) supplemented group and six participants in the olive oil group reported mild gastrointestinal adverse effects in Kristensen *et al*., (2016).

3.5. Risk of bias in individual studies

We used the Cochrane risk of bias tool (Higgins and Green, 2011) to assess all studies for their risk of bias within the following domains: selection bias, performance bias, detection bias, attrition bias, reporting bias, and other bias. Figure 2 provides an overview of the risk of bias assessment. Two studies had high risk for selective reporting bias (Venturini *et al.,* 2015, Olsen *et al*., 2000) and one study was classified as high risk for attrition bias (Tapsell *et al*., 2013). An intention-to-treat analysis was performed. The included studies were considered as having low risk for bias.

3.6. Results of the meta-analysis

Olive oil did not decrease SBP more than other fat, MDs = -0.11, CI 95 % (-0.68, 0.46), I^2 = 85.1%; *p* heterogeneity < 0.001. The studies dispensed liquid olive oil or capsules. To identify the effect of the two kinds of supplementation meta-analysis was stratified by this variable (capsules and oil) (Figure 3): no significant effect was observed either for capsules or liquid on SBP.

Olive oil showed a significant decrease in DBP with a fixed effects model of -0.73 mm Hg, 95% CI (-1.07, -0.40); $p < 0.001$; I^2 = 84.5%; *p* heterogeneity < 0.001. This effect was mainly due to liquid

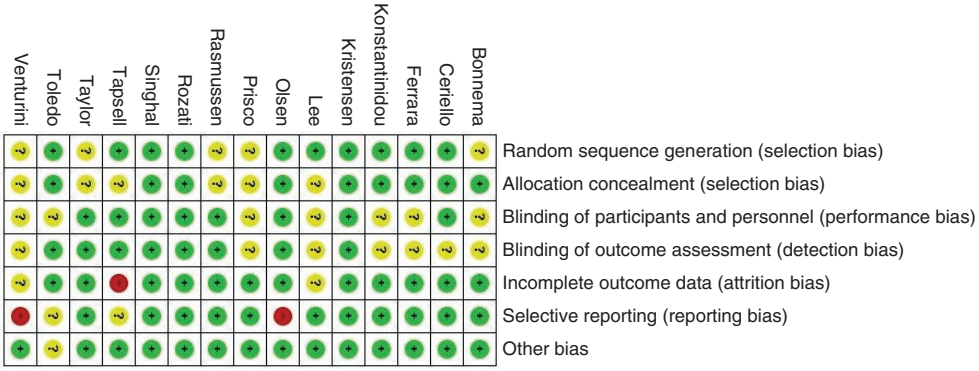

FIGURE 2. Risk of bias. For each study, each domain of bias is indicated as: low risk of bias in green, unclear risk of bias in yellow, and high risk of bias, in red.

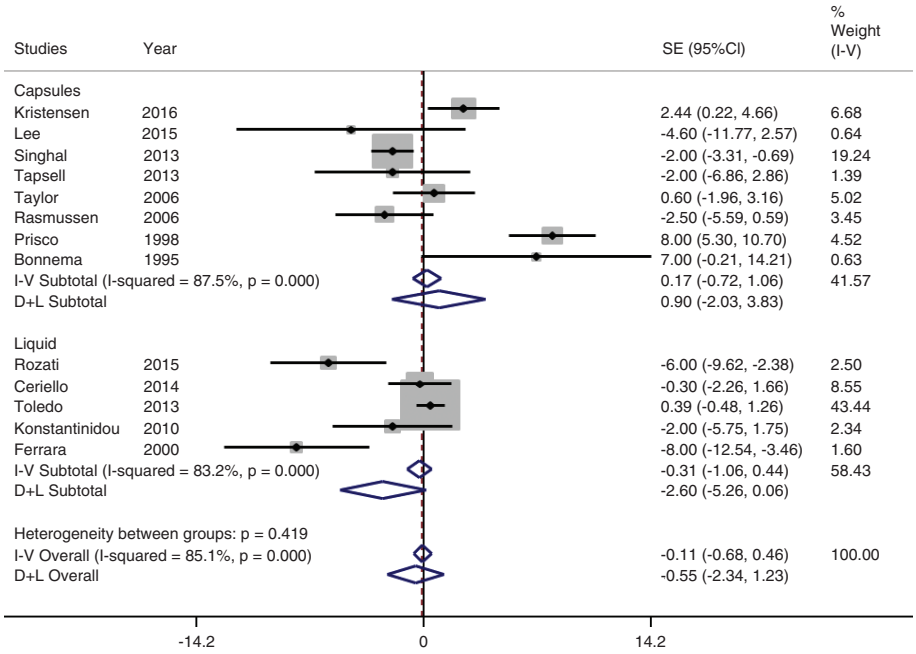

FIGURE 3. Meta-analysis of the effect of olive oil on systolic blood pressure, stratified by type of supplementation. The mean standard error of the change was computed. For each study, the shaded square represents the point estimate of the intervention effect. The individuals who have taken olive oil are located to the left of the forest plot.

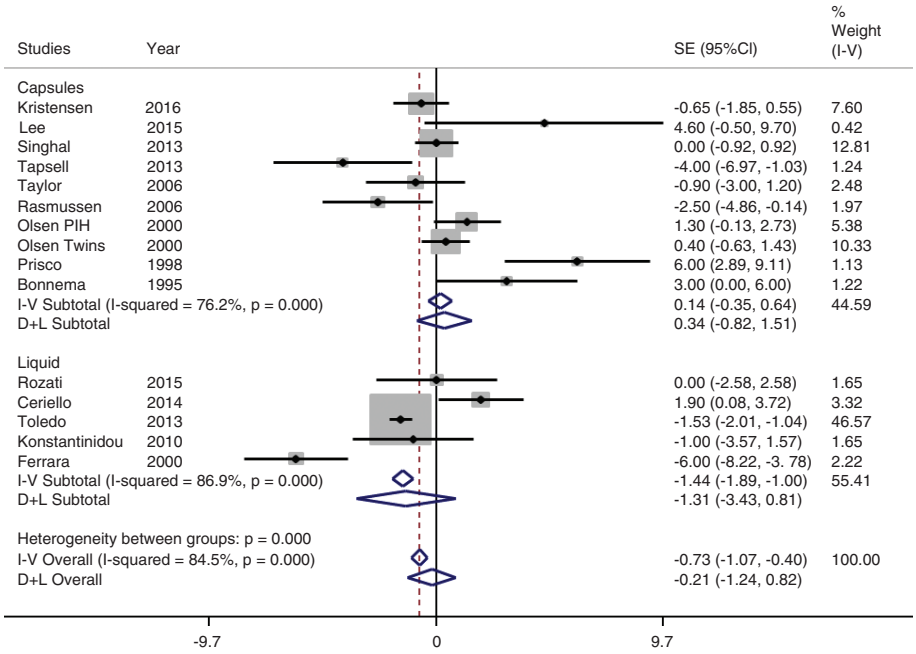

FIGURE 4. Meta-analysis of olive oil on diastolic blood pressure, stratified by type of supplementation. The mean standard error of the change was computed. For each study, the shaded square represents the point estimate of the intervention effect. The individuals who have taken olive oil are located to the left of the forest plot.

oil EVOO: a reduction of -1.44 mm Hg, 95% CI (-1.89, -1.00); p < 0.001; with a high heterogeneity, I^2 = 86.9%; *p* heterogeneity < 0.001. The olive oil in capsules had no significant influence on DBP, 0.14 mm Hg, 95% CI (-0.35, 0.64), I^2 = 76.2%, *p* = 0.5 (Figure 4). A meta-regression was performed to inquire the causes of heterogeneity. Neither the quantity of grams of olive oil on SBP (*p* = 0.35) or DBP (*p* = 0.51), nor the year of publication (*p* = 0.27 and *p* = 0.70, respectively), seem to be the cause of the heterogeneity found among the studies selected for the meta-analysis. Among the causes of heterogeneity are the different diets, and the characteristics of the patients for whom the studies were developed.

3.7. Risk of bias across studies (publication bias)

Egger's method showed *p* values of 0.67 and 0.23 for SBP and DBP, respectively.

4. DISCUSSION

In this systematic review of 6651 participants without previous cardiovascular events in 15 RCTs, comparing a diet enriched with olive oil versus a diet enriched with other fats, a significant reduction in DBP was observed, with high heterogeneity. This heterogeneity may be due to differences in the diets of control groups, characteristics of the populations (very different countries, with different risk factors, etc.), and the type of supplementation of olive oil. The EVOO seems to be the main factor responsible for the decrease in DBP. The PREDIMED trial (Toledo *et al.,* 2013) is the more influential study in the pooled results with a weight of 43.44% and 46.57% for SBP and DBP, respectively, and with more of the 70% of all subjects. The use of a random effects model implies giving a higher weight for much smaller studies, and more prone to bias than the PREDIMED. That is the reason we relied on the fixed effects model.

Considering the individual studies, a higher decrease in SBP was obtained with liquid EVOO, about 40 g in men and 30 g in women, compared to sunflower oil (Ferrara *et al*., 2000): -8 mm Hg in SBP, CI 95% (-12.5, -3.46), and -6 mm Hg in DBP, CI 95% (-8.22, -3.78). In another study (Rozati *et al*., 2015), EVOO (39 ± 7 g/day) significantly reduced SBP in -6 mm Hg, 95% CI (-9.62,-2.38), when compared with corn oil, soybean oil and butter together in an American diet. A lower reduction was observed with olive oil capsules (4 g) versus capsules of microalgae and palmitic acid: -2 mm Hg in SBP, 95% CI (-3.31, -0.69) (Singhal *et al*., 2013). In the PREDIMED trial after 3.8 years of follow-up (Toledo *et al*., 2013), liquid EVOO decreased DBP by -1.53 mm Hg, 95% CI (-2.01, -1.04). This reduction is similar to that found with olive oil capsules, compared to capsules containing fish oil (Rasmussen *et al.*, 2006), -2.5 mm Hg in DBP, 95% CI (-4.86, -0.14), and lower than reported in obese subjects (Tapsell *et al*., 2013): -4 mm Hg in DBP, 95% CI (-6.97, -1.03).

The study by Venturini *et al*., (2015), which could not be pooled as a mean difference could not be obtained, observed interesting results comparing

EVOO with a regular diet in participants with metabolic syndrome. They reported a decrease in the mean SBP of -5 mm Hg and -14 mm Hg in DBP.

Other studies with interventions of shorter duration than 12 weeks, not included in this review, showed significant reductions in blood pressure. In a double-blind crossover trial of 24 women, Moreno Luna *et al*., (2012) examined the influence of oil with high content in polyphenols on blood pressure: EVOO reduced SBP by -7.91 ± 9.51 mm Hg and DBP -6.65 ± 6.63 mm Hg. These effects are similar to those observed in a systematic review on the effect of first-line antihypertensive drugs choice (Wright and Musini, 2009). The effect of polyphenols has also been evaluated in a group of 160 healthy men from the North, Center and South of Europe (Bondia-Pons *et al*., 2007) in a randomized cross-over trial with three intervention periods: 25 ml/day of olive oil were administered with different concentrations of polyphenols. Both SBP and DBP decreased after consuming olive oil for nine weeks. In addition, the properties of virgin olive oil were evaluated in the SOLOS study in 40 men with stable coronary disease (Fitó *et al.*, 2005): SBP decreased after the intake of EVOO ($p < 0.001$), with no change in DBP. A systematic review on the effects of virgin olive oil polyphenols found significant differences in SBP and no effect on DBP (Hohmann *et al.*, 2015), although the number of pooled subjects is small, 69.

Olive oil seems to inhibit the activity of angiotensin-converting enzymes, and blocks the binding to angiotensin II receptor, and this hypotensive activity was demonstrated in studies on animals or humans (Patten *et al.,* 2016).

Among the strengths of this study is the exhaustive search developed without language restriction, the number of studies reviewed, and the quality of the included studies. The results could be extended to healthy subjects, with cardiovascular risk factors, type 2 diabetes, hypertension, overweight, obesity, and countries with distinct economic and social development. The main limitation of our systematic review is the heterogeneity among the studies. It could be justified because some studies have been carried out in areas with regular consumption of olive oil and it is possible that the group control has also taken olive oil. In addition, some participants have taken antihypertensive treatment for their underlying disease, thus decreasing the potential benefit of olive oil. Toledo *et al*., 2013, developed a study on individuals with different cardiovascular risk factors, including hypertension for which they need antihypertensive therapy, although the individuals were distributed into similar percentages between the intervention and control groups, 1666 (68%) patients in the extra virgin olive oil group and 1666 (70.9%) in the control group. Likewise, in Ferrara *et al.,* 2000, did a randomized crossover study in which there were basic conditions for all individuals. At the end of the follow-up, daily drug dosage was significantly reduced in the EVOO group, and 34.7% needed no antihypertensive therapy, while all patients required treatment during the sunflower oil diet. Physical activity may also vary among different populations.

Nevertheless, we consider that the number of studies on olive oil and blood pressure is still small. The intake of EVOO of between 10-50 ml per day can reduce diastolic blood pressure in healthy individuals or those with cardiovascular risk factors, even in hypertensive patients, and can be an important therapeutic tool. Further studies on EVOO are needed to reduce heterogeneity and consolidate the results.

5. CONCLUSIONS

The present meta-analysis provides evidence for a beneficial effect of EVOO on blood pressure in participants without cardiovascular events. Healthy individuals or those with cardiovascular risk factors can benefit from a reduction in DBP if they consume olive oil for at least three months.

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