Journal of Health, Population and Nutrition

RESEARCH

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Effect of olive oil consumption on diabetes risk: a dose-response meta-analysis

Yanbin Du[1] and Hua Zhou[2*]

Abstract

Background Diabetes is a common metabolic disease worldwide, is also a global major public health problem. We carried out this meta-analysis to evaluate the effects of olive oil(OO) consumption on diabetes.

Methods PubMed, Embase, Scopus, Web of Science and Cochrane Library databases were systematically searched until October 2024. Heterogeneity among studies was examined using Q and I^2 statistics. Combined risk ratio (RR) with their 95% confidence interval (CI) were calculated by using a random effects model. Also dose-response analysis and subgroup analysis were performed.

Results 10 studies (4 cohorts and 6 RCT) involved more than 50,0000 subjects and 2,0000 individuals with diabetes were included in the meta-analysis. A 13% (RR = 0.87, 95%CI = 0.83 – 0.92, $P < 0.01$) decreased risk of diabetes was shown in Cohort study and 22% (RR = 0.78, 95%CI = 0.70 – 0.88, $P < 0.01$) decreased risk in RCT study for the highest vs. lowest olive oil consumption. Subgroup analysis results showed that there was a better effect on reducing diabetes risk in age > 50 years(RR = 0.77, 95%CI = 0.70 – 0.89, $P < 0.01$), Europe(RR = 0.81, 95%CI = 0.72 – 0.86, $P < 0.01$) and extra virgin olive oil (RR = 0.75, 95%CI = 0.65–0.87, $P < 0.01$). Dose-response analysis showed a significant nonlinear association of diabetes risk with OO intake(Pnon-linearity < 0.05) and when 10–20 g of olive oil is consumed daily, the effect amount is statistically significant, while more than 20 g there was not statistically significant. Begg's and Egger's regression test results indicated that there was no publication bias and the results were reliable.

Conclusions Evidence from this meta-analysis suggested that OO consumption is associated with a decreased risk of diabetes, especially, 10–20 g OO daily may be beneficial for prevention and management of diabetes.

Keywords Olive oil, Diabetes risk, Diabetes prevention, Meta-analysis

Introduction

According to the latest report of the International diabetes Federation, as of 2023, 425 million people worldwide will have diabetes, accounting for 9.3% of the adult population [1]. In 2023, 11 million people worldwide will die of diabetes or its complications, which is equivalent to one person dying of diabetes every 8 s. This means that every year, more than the sum of cancer and AIDS deaths, people lose their lives because of diabetes. In addition, diabetes has a long course and repeated condition, which is very harmful to human health [2]. Diabetes is one of the main causes of renal failure and blindness.

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About 20 million people worldwide suffer from end-stage renal disease due to diabetes, of which about 15 million need dialysis or transplantation. About 35 million people suffer from retinopathy due to diabetes, of which about 2.7 million have become blind [3]. At present, diabetes has become a serious public health challenge for many developing countries.

Nutritional factors and dietary patterns play an important role in the etiology of various chronic diseases such as cardiovascular diseases and diabetes [4–6]. Mediterranean diet (MedDiet), which is widely regarded as the healthiest way of eating, it has been shown to prevent cancer, cardiovascular disease, coronary heart disease, obesity and diabetes [7–10]. Olive oil (OO), as a major part of the Mediterranean diet, is becoming more and more popular all over the world, whether OO has a beneficial effect on diabetes?

So far, there is no direct evidence showed that olive oil can reduce the risk of diabetes. Firstly, the earliest studies did not find that OO has a significant hypoglycemic effect [11–12]. Second, some previous clinical studies found beneficial effects of MUFAs on metabolic risk factors in T2D patients [13–15]. However, a recent study reported that MUFAs did not yield any significant effects on all-cause mortality and risk of cardiovascular disease [16]. And a recent meta-analysis published in 2017,they found that OO can lower the risk of diabetes with only included four cohort studies [17].

Hence, we carried this meta-analysis to explore whether eating olive oil is beneficial to diabetes, and the dose relationship between olive oil consumption and diabetes risk.

Materials and methods

This meta-analysis was planned and conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist(Registration number: CRD42024543816).

Literature search strategy

A systematic search of published articles was conducted in the PubMed, Embase, Scopus, Web of Science and Cochrane Library databases up to October 2024. We used the following search terms in title and abstract: ("olive oil" OR "lucca oil" OR "MUFAs") AND ("diabetes" OR "T2D" OR " blood glucose" OR "glycemic") AND ("Prospective studies" OR "cohort" OR "randomized controlled trial" OR "RCT" OR "controlled clinical trial" OR "clinical trial" OR "randomized" OR "random" OR "randomly" OR "Cross-over" OR "Parallel"). To enhance the comprehensiveness of literature search, we conduced backward and forward snowballing searches to identify additional relevant articles [18]. The literature search strategy can be found in the Supplementary materials A.

Inclusion and exclusion criteria

Studies that met the following criteria were included in the meta-analysis: (1) the studies in human were cohort studies or RCTs or case-control or cross-sectional studies; (2) the exposure of interest was OO consumption; (3) outcome is diabetes; (4) participants ⩾18 years of age; (5) relative risks (RRs) with their corresponding 95% confidence intervals(CIs) (or data can be calculated) had been provided. The exclusion criteria were the following: insufficient data or OO combined with other oils. Two of the authors independently searched all references, using a kappa statistic to assess the agreement between the authors [19]. When kappa value > 0.7, we accept the decision, otherwise reject the decision and request a third-party ruling.

2.3. Data extraction

Two authors (Yanbin DU and Hua ZHOU) performed data extraction, again any disagreements were discussed and resolved by consensus. The following information was collected from each eligible study: first author's name, publication year, country, exposure, study design, age and gender of participants, sample size, degree of OO consumption and assessment method, adjusted variables as well as effect estimators(OR, RR or HR) with corresponding 95%CI for the highest vs. lowest categories of OO consumption. The OR can be converted into RR according to the following formula: RR = OR/[(1-P0)+(P0*OR)], P0 represents the disease incidence rate of the control group. The calculation method of HR is similar to RR, but HR considers the time of the event occurrence.

Quality assessment and quality of evidence

The study quality of RCTs was assessed with the Cochrane Tool, which includes: selection bias, performance and detection bias, attrition bias, reporting bias and other possible sources of bias. Each domain was judged to have a "low risk", "high risk" or "unclear risk". And cohort studies was assessed using the Newcastle-Ottawa scale (NOS). Each study was assessed based on three broad perspectives: selection (0-4points), comparability (0-2points), and exposure (0-3points) with a score ranging from 0 to 9. We assigned scores of 0–3, 4–6, and 7–9 for low, moderate, and high quality of studies, respectively. Quality of evidence GRADE criteria were used to evaluate the overall certainty of the evidence in the meta-analyses.

Statistical analysis

We used dichotomous variables to study the relationship between OO consumption (highest vs. lowest) and diabetes risk. The relative risk (RR) and 95% confidence intervals(CI) were considered as the common

measurement. Use Q and I^2 statistics to estimate heterogeneity between studies. For the Q statistics, $P < 0.10$ indicated statistically significant heterogeneity. And the I^2 values of 25%, 25–50%, 50–75%, and > 75% were classified as indicating no, small, moderate, and significant heterogeneity, respectively. Pooled RRs were obtained using a random effects model, as a random-effects model is often more robust when synthesizing diverse studies [19]. In addition, we performed subgroup analysis using geography (European and America), sex (male and female), age (≤ 50 years and > 50 years), follow up years (≤ 4 years and > 4 years), olive oil type (EVOO and OO) and adjustment for family history, smoking and alcohol intake to explore the potential heterogeneity.

Based on the method described by Greenland and Longnecker (1996) and Orsini et al. (2012) [20–21], dose response analysis was conducted to further describe the relationship between OO consumption and diabetes risk. By using a constrained cubic spline regression model with three nodes at fixed percentiles (25%, 50%, and 75%) of the OO distribution, potential nonlinear correlations are examined. We plan to use the total OO consumption as an estimate, and convert different forms of OO consumption into daily OO grams. The weight of one milliliter of olive oil is approximately 0.92 g, we believe that 1 tablespoon is equivalent to 12 g of OO. The median or average OO intake for each category is assigned to the corresponding intake. If the intake of OO is within a certain range, the midpoint of the upper and lower limits is considered as the dose; If the highest category is open-ended, the midpoint of that category is set to 1.5 times the lower limit; If the lower limit of the lowest category is not provided, the assigned median is half of the upper limit of that category.

To assess potential publication bias, we used Begg's rank correlation and Egger's linear regression test [22]. Sensitivity analysis was conducted by excluding each study and reanalyzing the data. All statistical analyses were conducted using STATA 15.1 (STATA Corporation, Texas, USA).Significance was set at a $P < 0.05$ throughout except in heterogeneity test and all statistical tests were two-sided.

Results

Literature search

An electronic literature search identified 592 studies concerning OO consumption and the risk for diabetes, 582 of which were excluded based on the a series of reasons (165 duplicated articles, then 427 articles were screened by title and abstract, leading to exclusion of 265 irrelevant studies and 6 meta-analysis. Next, 86 reports, reviews, or letters, 27 non-human studies, 18 articles do not provide available data and 3 articles no comparison were removed. Finally, 5 studies OO combined with other oils, 3 studies do not have diagnostic criteria for diabetes and 4 studies are not highest vs. lowest OO consumption were excluded.), resulting in inclusion of a total of 10 studies in the meta-analysis. The details of literature search are shown in Fig. 1.

Study characteristics

The characteristics of included studies are shown in Table 1. The 10 studies (4 cohort [23–25] and 6 RCT [26–31]) that met the inclusion criteria for our meta-analysis were published between 2011 and 2023. Of these studies, two were carried out in USA [23, 30], five were carried out in Spain [26, 27–24, 28–29], one in china [31], and another was carried out in European countries [25], including UK, Greece, German, Denmark, Sweden, Italy, and Finland; In total, nearly 50,0000 subjects and 2,0000 individuals with diabetes were included in this meta-analysis. Mean ages of participants were between 18 and 80 years approximately. Two studies were conducted on female [23, 29], others are both sex. The type of OO consumption, four RCT studies [27, 28, 30–31] used Extra virgin olive oil (EVOO) and others did not provide detailed information about the OO. The follow up years ranged from 4 years to 22 years. All research is of medium to high quality.

Meta-analysis

Highest vs. lowest OO consumption and diabetes risk

The overall analysis of diabetes risk among the individuals with highest compared with the lowest (never/almost never) OO consumption (10,6764 cases and 40,1150 controls from 10 studies). The summary RR showed that a 13% (RR = 0.87, 95%CI = 0.83 – 0.92, $P < 0.01$) decreased risk of diabetes in Cohort studies with no heterogeneity was observed (Q = 1.19, $P = 0.938 > 0.1$, $I^2 = 0\%$) and 22% (RR = 0.78, 95%CI = 0.70 – 0.88, $P < 0.01$) decreased risk in RCT studies for the highest vs. lowest OO consumption with no heterogeneity was observed (Q = 0.06, $P = 0.682 > 0.1$, $I^2 = 0\%$). According to the GRADE approach (Table 2), RR was considered to have a moderate quality of evidence. A forest plot is shown in Fig. 2.

Subgroup analysis and meta-regression analysis

To further explore the association between OO consumption and diabetes risk, we conducted a subgroup analysis. The results showed that people in Europe have a lower risk of diabetes than America (Europe: RR = 0.81, 95%CI = 0.72–0.85,$P < 0.01$; America: RR = 0.89, 95%CI = 0.79–0.94,$P < 0.01$); EVOO showed a lower risk of diabetes than OO (EVOO: RR = 0.75, 95%CI = 0.65–0.87,$P < 0.01$; OO: RR = 0.87, 95%CI = 0.83–0.92,$P < 0.01$); And more beneficial impact was found on age > 50 years (RR = 0.77, 95%CI = 0.70–0.89,$P < 0.01$). In addition, a lower risk of diabetes was observed in the stratified study

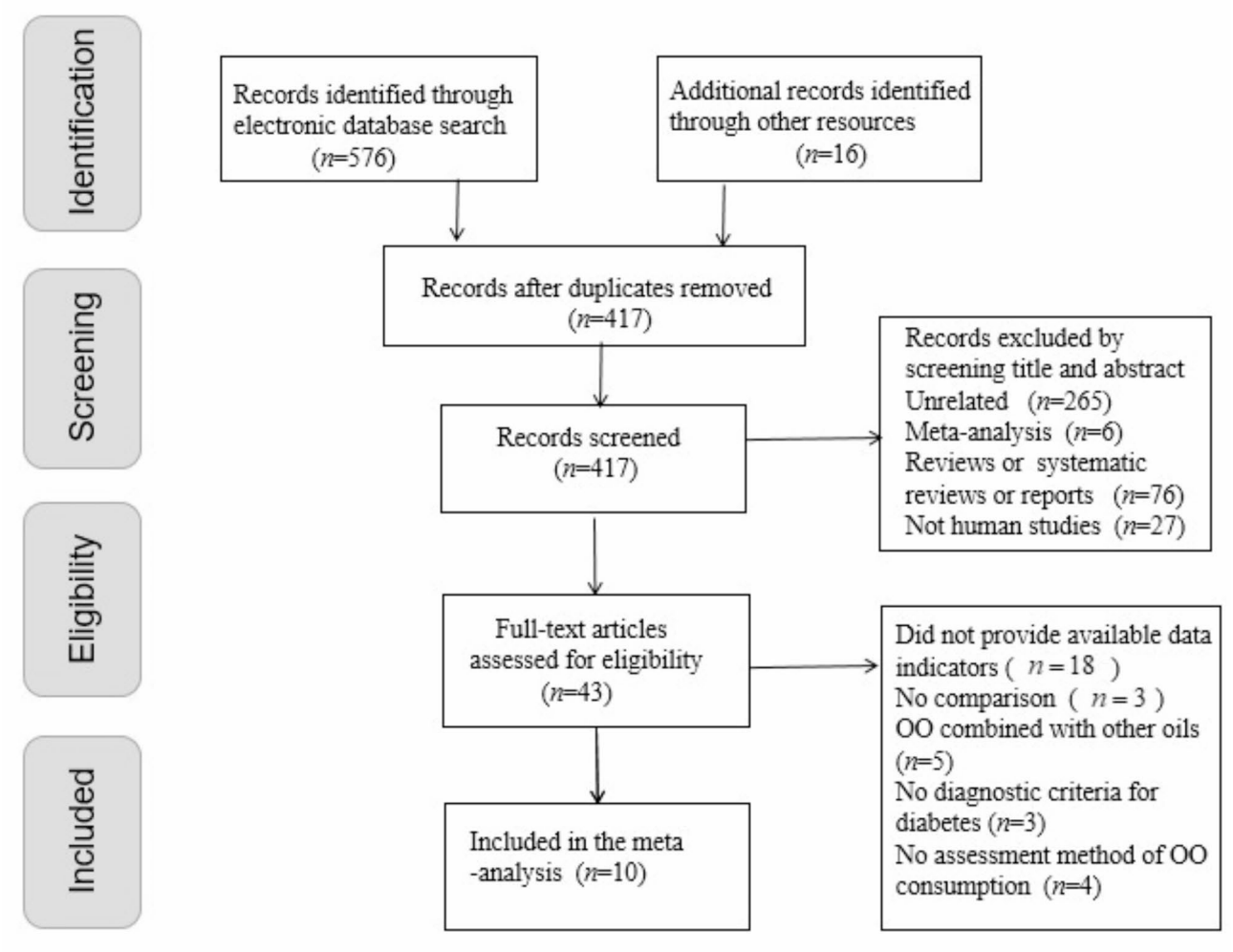

Fig. 1 Flowchart of study search procedure

of adjustment for alcohol intake(RR = 0.69, 95%CI = 0.53–0.90,$P < 0.01$) and adjustment for family history of diabetes (RR = 0.77, 95%CI = 0.68–0.92,$P < 0.01$). (Table 3)

Meta-regression analysis results showed that age (Coef.=-0.0002119, $p = 0.965$) and follow up years(Coef.=0.0029977, $p = 0.707$) had no significant influence on the association between consumption of olive oil and risk of diabetes.(Fig. 3).

Dose–response analysis

Three articles [23, 25, 30] were included in the dose-analysis. By using a constrained cubic spline regression model with three nodes at fixed percentiles (25%, 50%, and 75%) of the OO distribution, a non-linear dose-response association was detected for OO intake and diabetes risk ($p_{non\text{-}linearity}$ <0.05). (Fig. 4) Sold line and long dashed lines represent RR and its 95% confidence interval. If the 95% CI intersects with 1, it indicated that there was no statistical significance. It can be seen when OO intake of 10–20 g per day, the effect amount is statistically significant, while more than 20 g per day there was not statistically significant.

Sensitivity analysis and publication bias

Sensitivity analyses were carried out by excluding each study and reanalyzing the data, the results showed that the pooled RR has no great change by exclusion of each study, RR altered between 0.73 and 0.96. (Fig. 5). No publication bias was detected in current meta-analysis of the association between OO consumption and risk of diabetes. Begg's rank correlation and Egger's liner regression test was not statistically significant (Begg's: $P = 0.246$, Egger's: 0.151).

Discussion

This meta-analysis evaluated the association between OO consumption and diabetes risk with a sample size of over 50,0000 from 10 studies published between 2011 and 2023. The direct evidence from this meta-analysis

Table 1 Characteristics of studies included in the meta-analysis

Author and Publication Year	Study Design	Country	Age and Sex	Follow up years	Sample Size total/cases	Assessment Method	Adjusted OR (95%CI) (high vs. low intake)	Adjusted variables	Quality
Santos Lozano et al., 2019 [23]	RCT Name: PREDIABO LE	Spain	30–80, both	2.5	3826/48	FFQ 55 ml/d olive oil	0.45 (0.24–0.83)	Age, sex, BMI, smoking, family history of hypertension / diabetes, alcohol, sedentary lifestyle, physical activity	moderate
Guasch Ferre et al., 2015 [24]	Cohort Name: NHS NHS II	USA	37–65, F 26–45, F	22	59,930/5738 85,157/3914	FFQ 0–20 g/d 0–30 g/d	F: 0.91 (0.81–1.01) F: 0.87 (0.73–1.04)	Age, ethnicity, ancestry, smoking, physical activity, family history of hypercholesterolemia /hypertension / diabetes multivitamin use, total energy intake, BMI	high
Salas-Salvado et al., 2014 [25]	RCT Name: PREDIMED	Spain	55–80, both	4	2301/181	Intervention 50 ml/d EVOO	0.60 (0.43–0.84)	Age, sex, BMI, smoking, fasting glucose level, prevalence of dyslipidemia and hypertension, energy intake, adherence to MedDiet, physical activity, education level, and alcohol intake level	moderate
Mari-Sanchis et al., 2011 [26]	Cohort Name: SUN	Spain	18–75, both	5.7	10,491/42	SFFQ	0.76 (0.39–1.48)	physical activity, smoking, gestational diabetes, hypertension, hypercholesterolemia, energy intake, family history of diabetes, alcohol intake, fruit intake, sugar sweetened beverages, sleep apnea, caffeine intake	high
Romaguera et al., 2011 [27]	Cohort Name: The Interact	Europe	25–70,both	3.99	340,234/11,994	Validated questionnaires	HR 0.65 (0.60–0.71)	BMI, educational level, physical activity, smoking status, and total calorie intake	moderate
Carla Assaf-Balut et al.,2017 [28]	RCT	Spain	32.7 ± 5.3, F	19 months	2418/252	Intervention 40 mL/d of EVOO	0.74(0.56–0.97)	age (continuous), ethnicity and parity, BMI, Family history	moderate

Table 1 (continued)

Author and Publication Year	Study Design	Country	Age and Sex	Follow up years	Sample Size total/cases	Assessment Method	Adjusted OR (95%CI) (high vs. low intake)	Adjusted variables	Quality
Jesús F, et al.,2023 [29]	RCT	Spain	67 ± 6,both	7	1837/707	FFQ Total olive oil	0.40 (0.37, 0.44)	BMI, smoking status, alcohol intake, education level, physical activity, family history of CHD, dyslipidemia, hypertension, and dyslipidemia and hypertension treatment.	moderate
Salas-Salvadó J, et al., 2014 [30]	RCT	USA	55–80,both	4	3833/1261	50 mL/d EVOO	0.79(0.62,1.09))	age, sex, body mass index, smoking status, fasting glucose, dyslipidemia, hypertension, total energy intake	high
Zhao, et al.,2021 [31]	RCT	China	28 ± 5.2,both	3	550/123	25–30 g/d EVOO	0.74(0.49–0.99)	age, BMI, gestational, personal and family history, and smoking status	high

Abbreviations: F: female; M: male; Both: female and male; BMI: body mass index; FFQ: food frequency questionnaire; EVOO: extra virgin olive oil

Table 2 Summary of findings and quality of evidence assessment using GRADE approach

Study design	Summary findings		Quality of evidence assessment(GRADE)					
	No of patients (meta-analysis)	RR (95%CI)	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Quality of evidence
Cohort	21,688(4)	0.87 (0.83,0.92)	Not serious	Not serious	Serious	Not serious	Not serious	Moderate
RCT	2572(6)	0.78 (0.70,0.88)	Not serious	Not serious	Serious	Not serious	Not serious	Moderate

revealed OO intake as being associated with a decreased risk to develop diabetes.

Our results were in agreement with some previous studies, in a 10-year follow-up study, T2D incidence was lower with OO supplemented MedDiet compared with MedDiet, and this corresponded to lower hazard ratios (0.60 vs. 0.82) [23]. The current evidence on OO in diabetes prevention mainly stems from meta-analyses, which have shown that OO is the key of MedDiet and responsible for alleviating diabetes metabolic risk factors and reducing all-cause mortality, stroke, and CVD events [32–33]. Our research results provides a direct and strong evidence that olive oil consumption can reduce the risk of diabetes. There is a 13% reduced risk of diabetes in Cohort studies and 22% reduced risk of diabetes in RCT studies for highest compared with the lowest (never/almost never) OO consumption. Dose analysis showed that there was a non-linear association between OO intake and diabetes risk. For patients with diabetes, it may be more appropriate to take 10–20 g olive oil every day to avoid excessive calories leading to weight gain or abnormal blood lipids. Excessive consumption of olive oil may lead to obesity, hyperlipidemia, and decreased digestive function.

Subgroup analysis demonstrated that there was a significant difference in age. Older people (age > 50 years) are more susceptible to the protective effects of OO; It is well known that aging is associated with dysregulated immune function and increased susceptibility to metabolic syndrome, which can increase the risk of diabetes. Europeans have a lower risk of diabetes than Americans, which may be related to different dietary patterns and cultural differences. Many European countries adhere to the Mediterranean dietary pattern. In addition, the extra virgin olive oil (EVOO) showed a lower risk of diabetes than OO. The EVOO contains high amounts of bioactive compounds such as squalene, phytosterols, triterpenoids, carotenoids, tocopherols and also a wide variety of

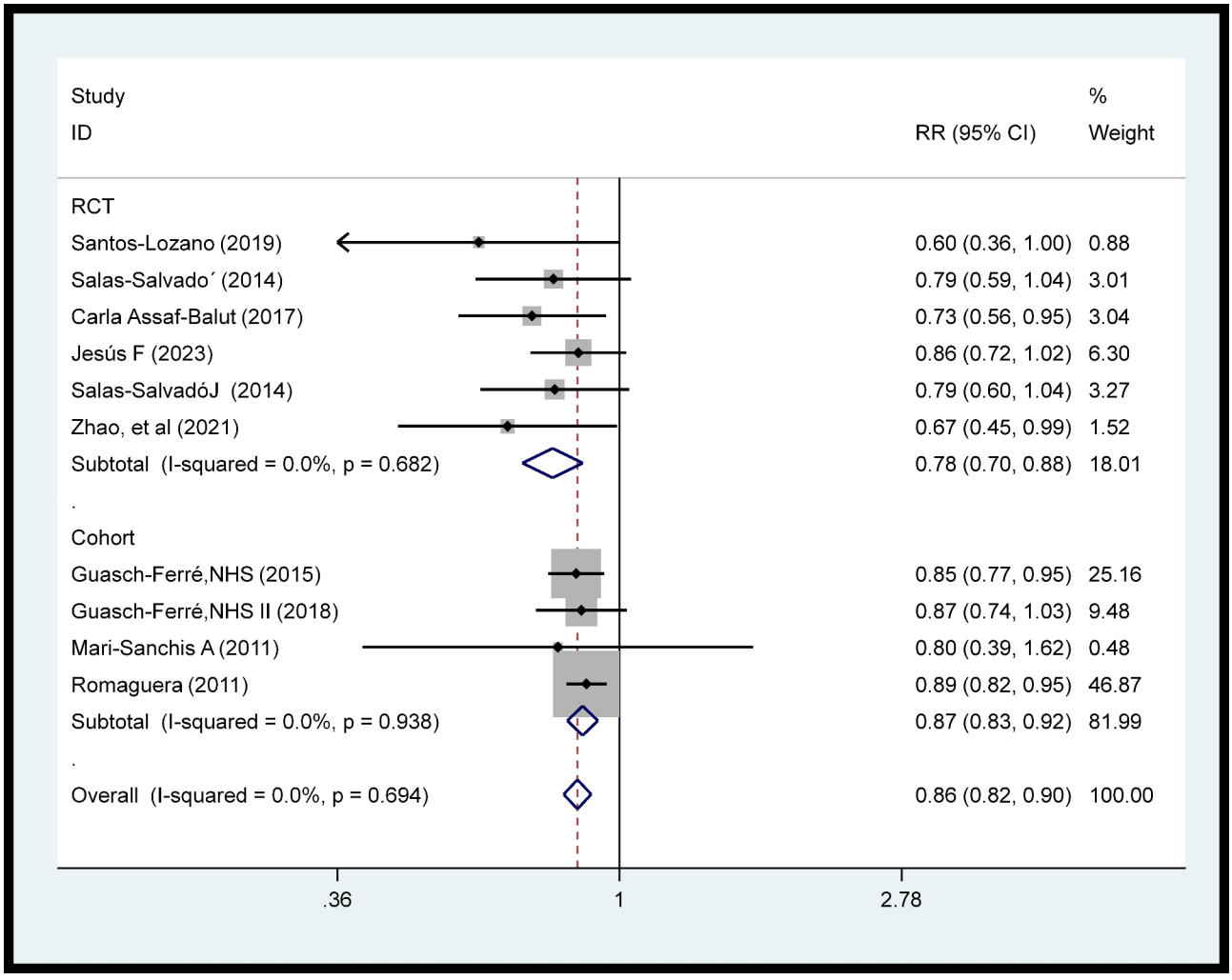

Fig. 2 Effects of highest vs. lowest OO consumption on diabetes risk using a fixed effects model

phenolic compounds including secoiridoids (oleuropein) and their phenolic derivates (tyrosol and hydroxytyrosol), flavonoids (luteolin) and lignans [34]. Similar research also found EVOO could effectively reduce blood lipid concentration than other types of OO [35]. Some studies found that diabetes has a certain genetic susceptibility, and there is a phenomenon of family aggregation. People with a family history of diabetes have a higher risk of diabetes. Drinking alcohol also had a significant impact on patients with diabetes, which may lead to blood sugar fluctuations, increase the risk of complications and interfere with drug effects. Long term heavy alcohol consumption may lead to high blood sugar, as the carbohydrates in alcohol are metabolized into sugars in the body.

The reduced impact of OO on the risk of diabetes may be due to its fatty acid composition. The fatty acids of OO are composed of 55–83% MUFA (oleic acid), 4–20% polyunsaturated fatty acids (PUFA), 8–14% SFA, and almost 1–2% minor components [36]. It has been suggested that replacing SFAs with MUFA can lower serum cholesterol levels [37]. Epidemiological data show that dyslipidemia is an important predisposing factor for diabetes. MUFA can improve blood glucose response, increase insulin sensitivity, reduce insulin resistance and insulin demand, lower total cholesterol (TC), triglycerides (TG), and low-density lipoprotein (LDL-c) in the blood, and increase high-density lipoprotein. In a recent meta-analysis of randomized controlled trials conducted by Qian et al. in 2016 [38], a high MUFA diet showed a more significant decrease in fasting blood glucose levels compared to a high carbohydrate and high polyunsaturated fatty acid diet.

This meta-analysis has its own strengths. First, this is the first study that examines association of OO consumption with diabetes risk using the dose-response meta-analysis approach. Second, we synthesized and quantified evidence from both prospective cohort studies and RCTs, the results confirmed that OO consumption was associated with a decreased risk of diabetes. Third, the present study can serve as a reference and indication for nutrition

Table 3 Summary effects overall in the subgroups

Subgroups	Study number	RR (95%CI)	*P*-value	Heterogeneity test		
				Q	*P*-value	I^2(%)
Overall	10	0.86 (0.82, 0.89)	< 0.01	10.52	0.694	0
Study type						
Cohort	4	0.87 (0.83, 0.92)	< 0.01	1.19	0.938	0
RCT	6	0.78 (0.7, 0.88)	< 0.01	0.06	0.682	0
Sex						
Female	3	0.89 (0.79, 0.97)	< 0.01	1.13	0.57	0
Both	7	0.83 (0.53, 0.90)	< 0.01	0.10	0.75	0
Age						
≤ 50 years	5	0.87 (0.73–1.04)	< 0.01	1.56	0.62	0
> 50 years	5	0.77 (0.70, 0.89)	< 0.01	2.47	0.48	0
Follow up years						
≤ 4 years	6	0.84 (0.79, 0.89)	< 0.01	5.24	0.13	0
> 4 years	4	0.86 (0.69, 0.91)	< 0.01	8.16	0.11	0
Geography						
Europe	6	0.81 (0.72, 0.85)	< 0.01	1.46	0.48	0
America	3	0.89 (0.79, 0.94)	< 0.01	0.04	0.85	0
Types of olive oil						
OO	6	0.87 (0.83, 0.92)	< 0.01	2.53	0.772	0
EVOO	4	0.75 (0.65, 0.87)	< 0.01	0.64	0.886	0
Adjustment for family history						
Yes	6	0.77 (0.68, 0.92)	< 0.01	2.83	0.3	0
No	4	0.87 (0.77, 0.96)	< 0.01	0.03	0.85	0
Adjustment for smoking						
Yes	7	0.83 (0.69–0.94)	< 0.01	2.39	0.02	0
No	3	0.87 (0.78–0.85)	< 0.01	1.08	0.11	0
Adjustment for alcohol intake						
Yes	3	0.69 (0.53, 0.90)	< 0.01	0.1	0.75	0
No	7	0.89 (0.73, 0.97)	< 0.01	1.13	0.57	0

RR: Risk ratio; 95%CI: 95%Confidence interval; RCT: randomized controlled trial; BMI: body mass index

therapy of the diabetes and clinical management of diabetes in clinical medicine.

Limitations

Firstly, our study is limited because of the small sample size of 10 studies for investigating OO consumption and risk of diabetes. Although we did not restricted our searches based on language, just studies from English databases and missed non-English articles may affect the final results. Secondly, OO were reported in different units and different type of diets, this may affect the reliability of the results to some extent.

Future directions

For the next step of research, it is necessary to clarify the mechanism by which olive oil lowers the risk of diabetes. In addition, more clinical trials are needed to clarify the appropriate daily dosage of OO consumed by different populations, especially for people with chronic diseases.

Conclusion

In conclusion, direct evidence from this meta-analysis indicated that OO consumption is associated with a decreased risk of diabetes. And dose-response analysis showed that 10–20 g OO daily may be effective to manage and prevent diabetes. Further studies are required to explore the mechanism of OO in reducing diabetes risk.

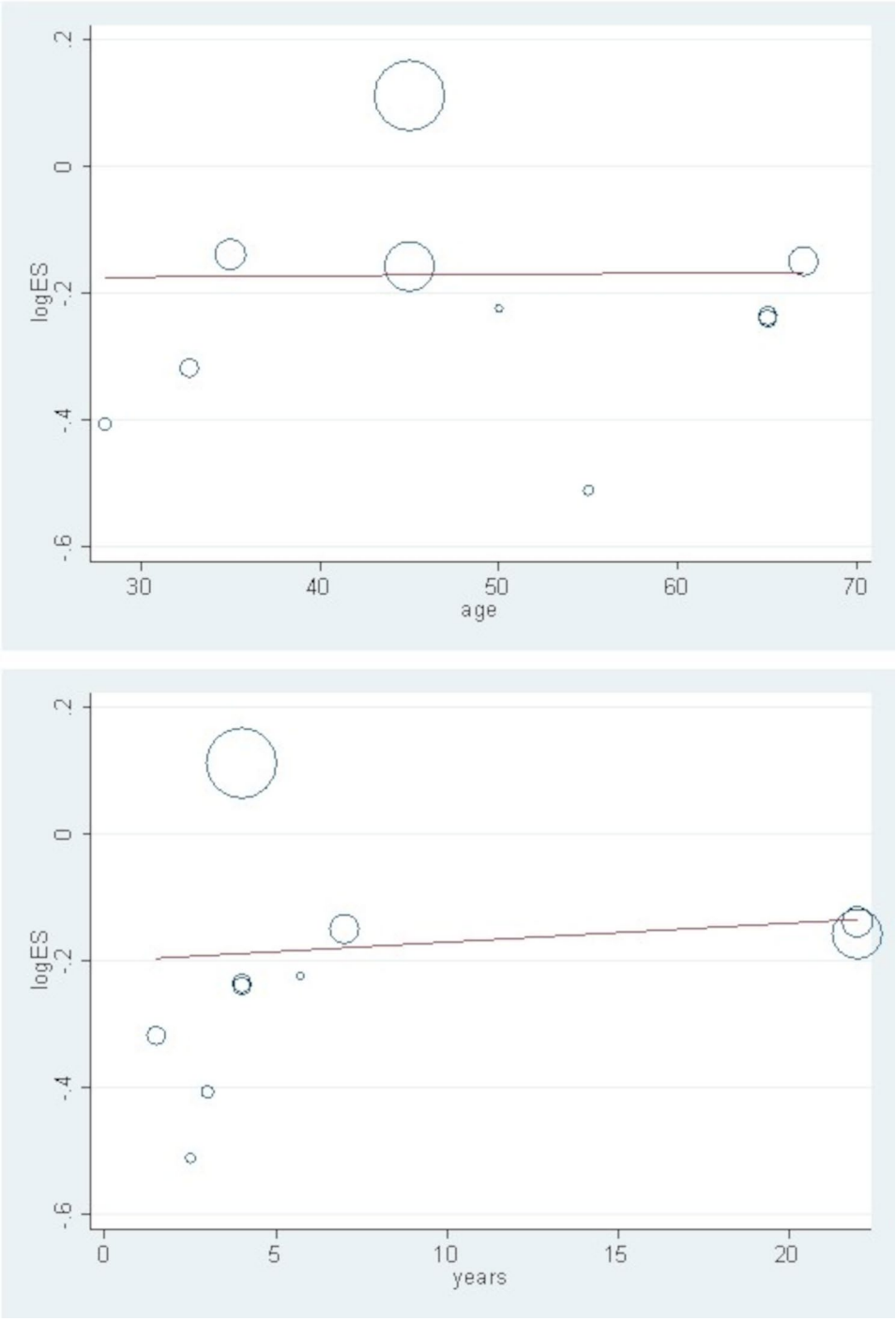

Fig. 3 Meta-regression analysis of the influence of age and follow-up years on the association between olive oil and diabetes risk

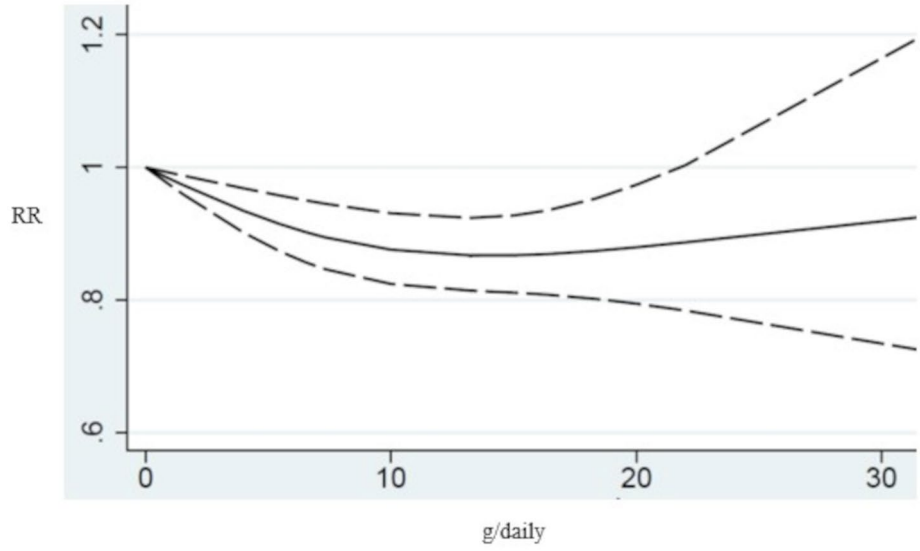

Fig. 4 Non-linear dose-response relationship between OO intake (g/daily) and risk of diabetes($P_{non-linearity} < 0.05$). Sold line and long dashed lines represent relative risk and its 95% confidence interval

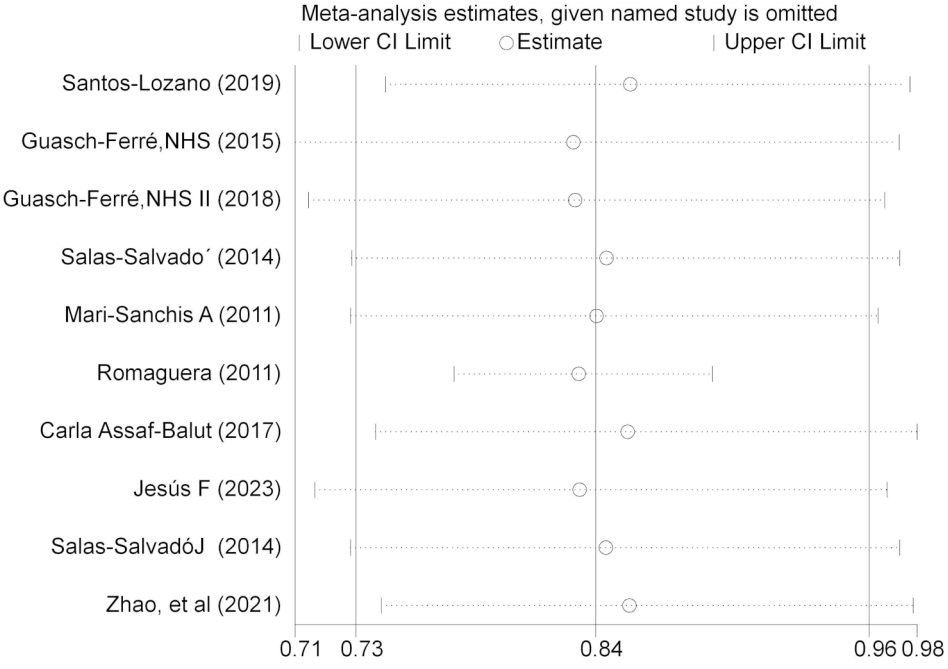

Fig. 5 Sensitivity analysis result chart

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s41043-025-00866-7.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Author contributions

Yanbin Du conceived the idea, performed the statistical analysis and drafted this meta-analysis. Hua Zhou and Yanbin Du conducted the systematic search, screened the articles and extracted the data. Hua Zhou is the guarantor of the overall content. All authors revised and approved the final manuscript.

Data availability

Data will be provided in the Supplementary materials B.

Declarations

Ethics approval and consent to participate
Not applicable.

Conflict of interest
The authors declare no conflict of interest.

Received: 22 August 2024 / Accepted: 5 April 2025
Published online: 24 April 2025

References

1. WHO. World Health Organization (WHO) Global Report on Diabetes. (2016) Available online: http://www.who.int/diabetes/global-report/en/ (accessed on 12 September 2017).
2. IDF Diabetes Atlas. (2015).7th Edition. Available online: http://www.diabetesatlas.org/
3. Kalyani RR, Corriere M, Ferrucci L. Age-Related and Disease-Related muscle loss: the effect of diabetes, obesity, and other Diseases[J]. Lancet Diabetes Endocrinol. 2014;2:819–29.
4. Msc MB, Msc MM, Shahram APD et al. Effect of probiotic, prebiotic, and synbiotic supplementation on cardiometabolic and oxidative stress parameters in patients with chronic kidney disease: A systematic review and Meta-analysis[J].Clinical therapeutics, 2021, 43(3).https://doi.org/10.1016/j.clinthera.2020.12.021
5. Morvaridzadeh M, Sepidarkish M, Fazelian S, et al. Effect of calcium and vitamin D Co-supplementation on blood pressure: A systematic review and Meta-Analysis[J]. Clin Ther. 2020;42(3). https://doi.org/10.1016/j.clinthera.2020.01.005.
6. Rahimlou M, Mirzaei K, Keshavarz SA, et al. Association of Circulating adipokines with metabolic dyslipidemia in obese versus non-obese individuals[J]. Diabetes & Metabolic Syndrome; 2016. pp. S60–5.
7. Verberneab L, Bach-Faigc A. J] Nutr Cancer. 2010;62(7):860–70. Genevieve Bucklandd & Lluís Serra-Majemac.Association between the Mediterranean diet and cancer risk: a review of observational studies.[
8. Michael G, Meropi K, Nikos Y. Mediterranean diet and diabetes: prevention and treatment. Nutrients. 2014;6(4):1406–23.
9. Rosenberg KM. Diet superior to Low-Fat diet for CVD Prevention[J]. Am J Nurs. 2022;122(9):62.
10. Lubia. Velázquez-López,Gerardo Santiago-Díaz,Julia Nava-Hernández. Mediterranean-style diet reduces metabolic syndrome components in obese children and adolescents with obesity[J]. BMC Pediatr. 2014;14(1):1–10.
11. George ES, Marshall S, Mayr HL et al. The effect of high-polyphenol extra Virgin Olive oil on cardiovascular risk factors: a systematic review and meta-analysis. Crit Reviews Food Sci Nutr,2018, (10):1.
12. Lopez-Miranda J, Perez-Jimenez F, Ros E, De Caterina R, Badimon L, Covas MI et al. Olive oil and health: summary of the II International Conference on Olive Oil and Health Consensus Report, Jaen and Cordoba (Spain) 2008. *Nutr Metab Cardiovasc Dis*,2010, 20: 284–294.
13. Schwingshackl L, Strasser B, Hoffmann G. Effects of monounsaturated fatty acids on glycaemic control in patients with abnormal glucose metabolism: a systematic review and meta-analysis. Ann Nutr Metab. 2011;58:290–6.
14. Schwingshackl L, Strasser B. High-MUFA diets reduce fasting glucose in patients with type 2 diabetes. Ann Nutr Metab. 2012;60:33–4.
15. Gillingham LG, Harris-Janz S, Jones PJH. Dietary monounsaturated fatty acids are protective against metabolic syndrome and cardiovascular disease risk factors. Lipids. 2011;46(3):209–28.
16. Chowdhury R, Warnakula S, Kunutsor S, Crowe F, Ward HA, Johnson L, Di Angelantonio E. Association of dietary, Circulating, and supplement fatty acids with coronary risk. Ann Intern Med. 2014;160(6):398.
17. Schwingshackl L, Lampousi A-M, Portillo MP, Romaguera D, Hoffmann G, Boeing H. Olive oil in the prevention and management of type 2 diabetes mellitus: a systematic review and meta-analysis of cohort studies and intervention trials. Nutr Diabetes. 2017;7(4):e262–262.
18. Wohlin C. Guidelines for snowballing in systematic literature studies and a replication in software engineering[J].ACM, 2014.https://doi.org/10.1145/2601248.2601268
19. Musazadeh V, Kavyani Z, Naghshbandi B, Dehghan P, Vajdi M. The beneficial effects of omega-3 polyunsaturated fatty acids on controlling blood pressure: an umbrella meta-analysis. Front Nutr. 2022;9:985451. https://doi.org/10.3389/fnut.2022.985451.
20. Greenland S, Longnecker MP. Methods for trend Estimation from summarized dose–response data, with applications to meta-analysis. Am J Epidemiol. 1992;135(11):1301–9.
21. Orsini N, Li R, Wolk A, Khudyakov P, Spiegelman D. Meta-analysis for linear and nonlinear dose-response relations: examples, an evaluation of approximations, and software. Am J Epidemiol. 2012;175(1):66–73.
22. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. BMJ (Clinical Res Ed. 1997;315:629–34.
23. Guasch-Ferre M, Hruby A, Salas-Salvado J, et al. Olive oil consumption and risk of type 2 diabetes in US women. Am J Clin Nutr. 2015;102:479–86.
24. Mari-Sanchis A, Beunza JJ, Bes-Rastrollo M, et al. Olive oil consumption and incidence of diabetes mellitus, in the Spanish sun cohort. Nutr Hosp. 2011;26:137–43.
25. Romaguera D, Guevara M, Norat T, et al. Mediterranean diet and type 2 diabetes risk in the European prospective investigation into cancer and nutrition (EPIC) study: the interact project. Diabetes Care. 2011;34:1913–8.
26. Santos-Lozano JM, Rada M, Lapetra J, et al. Prevention of type 2 diabetes in prediabetic patients by using functional Olive oil enriched in oleanolic acid: the PREDIABOLE study, a randomized controlled trial[J].Diabetes. Obes Metabolism. 2019. https://doi.org/10.1111/dom.13838.
27. Salas-Salvado J, Bullo M, Estruch R, et al. Prevention of diabetes with mediterranean diets: a subgroup analysis of a randomized trial. Ann Intern Med. 2014;160:1–10.
28. de la Carla AB et al. Torre Nuria,Durán AlejandraA Mediterranean diet with additional extra virgin olive oil and pistachios reduces the incidence of gestational diabetes mellitus (GDM): A randomized controlled trial: The St. Carlos GDM prevention study[J].PloS one, 2017, 12(10):e0185873.
29. García-Gavilán JF, Babio N, Toledo E, et al. Olive oil consumption, plasma metabolites, and risk of type 2 diabetes and cardiovascular disease. Cardiovasc Diabetol. 2023;340. https://doi.org/10.1186/s12933-023-02066-1.
30. Salas-Salvadó J, Bulló M, Estruch R, et al. Prevention of diabetes with mediterranean diets: a subgroup analysis of a randomized trial. Ann Intern Med. 2014;160:1–10.
31. Zhao L, Zhang P, Zheng Q et al. Does a MediDiet with additional extra Virgin Olive oil (EVOO) and pistachios reduce the incidence of gestational diabetes?[J].Endocrine practice: official journal of the American college of endocrinology and the American association of clinical endocrinologists, 2021.https://doi.org/10.1016/j.eprac.2021.08.010
32. Martinez-Gonzalez MA, Sayon-Orea C, Bullon-Vela V et al. Effect of Olive oil consumption on cardiovascular disease, cancer, type 2 diabetes, and all-cause mortality: A systematic review and meta-analysis[J].Clinical nutrition, 2022.https://doi.org/10.1016/j.clnu.2022.10.001
33. Zhao L, Zhang P, Zheng Q et al. Does a MediDiet with additional extra Virgin Olive oil and pistachios reduce the incidence of gestational Diabetes?[J]. Endocrine practice: official journal of the American college of endocrinology and the American association of clinical endocrinologists, 2022, 28(2):135–41.
34. Servili Maurizio S, Beatrice E, Sonia U, Stefania. Veneziani Gianluca, & Di Maio Ilona. Biological activities of phenolic compounds of extra Virgin Olive oil. Antioxidants. 2013;3(1):1–23.
35. Atefi M, Gholam R. Pishdad, Canola oil and Olive oil impact on lipid profile and blood pressure in women with type 2 diabetes: a randomized, controlled trial[J].Progress in nutrition, 2018, 20(1):102–9.
36. Slama A, Zouhir A, Cherif A. Influence of the heating process on the total phenols and fatty acids composition of Virgin Olive oil originated in Tunisia, Italy, and Spain[J]. Volume 101. Rivista Italiana delle Sostanze Grasse; 2024. 2.
37. Lu Y, Zhao J, Xin Q, et al. Protective effects of oleic acid and polyphenols in extra Virgin Olive oil on cardiovascular diseases[J]. Food Sci Hum Wellness. 2024;13(2):529–40.
38. Qian F, Korat AA, Malik V, Hu FB. Metabolic effects of monounsaturated fatty Acid–Enriched diets compared with carbohydrate or polyunsaturated fatty Acid–Enriched diets in patients with type 2 diabetes: A systematic review and Meta-analysis of randomized controlled trials. Diabetes Care. 2016;39(8):1448–57.

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