

Review

Olive oil and longevity

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Several lines of evidence point to olive oil and the olive oil-centered Mediterranean diet as conducive to longevity. The evidence stems from ecological, as well as analytic epidemiological studies assessing olive oil, monounsaturated lipids or the Mediterranean dietary pattern in relation to the incidence of, or mortality from, major common diseases, or overall mortality. Mechanistic considerations are addressed by biochemical studies, whereas randomized clinical trials provide further support to the evidence generated from observational investigations. The content of olive oil in several microcomponents with antioxidant potential, as well as its high content in monounsaturated lipids appear to be essential for the beneficial effect of this food.

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1 Introduction

Olive oil is an integral part of the diets of the Mediterranean populations. Although different regions in the Mediterranean basin have their own diets, several common characteristics can be identified, most of which stem from the fact that olive oil occupies a central position in all of them [1]. Indeed, it would have been impossible to consume the high quantities of vegetables and legumes, which characterize the Mediterranean dietary pattern, were it not for olive oil that is traditionally used in the preparation of these dishes. Although figures may vary by time and place, olive oil contributes almost 20% of the total energy intake in Mediterranean menus. Since olive oil is rarely, if ever, used in isolation, it is difficult to disentangle the effects of olive oil *per se* from those of the Mediterranean diet as a whole. Indeed, even randomized intervention trials cannot properly evaluate the importance of olive oil. This is because diets under comparison need to be isocaloric, which implies that the addition of olive oil has to be accompanied by reduction of another energy-generating nutrient, a substitution that may or may not be neutral with respect to the outcome under investigation [2]. Thus, the effects of olive oil on health and disease have frequently been assessed through epidemiological studies focusing on the Mediterranean diet. In these

studies, the isolation of the effects of olive oil must rely on statistical assumptions and procedures, viewed in the context of our understanding of the biological properties of olive oil and the other components of the Mediterranean diet.

2 Studies of olive oil in relation to health and disease

Studies evaluating the role of Mediterranean diet and/or olive oil on health and disease can be distinguished into six categories:

- (i) Ecological studies correlating Mediterranean dietary patterns or olive oil consumption with overall or cause-specific mortality;
- (ii) Case-control studies assessing the role of olive oil on the occurrence of major chronic diseases;
- (iii) Epidemiological studies in non-Mediterranean countries assessing the role of Mediterranean-like dietary patterns or monounsaturated lipids (the dominant chemical constituent of olive oil) on the incidence of, or mortality from, selected diseases or groups of diseases;
- (iv) Biochemical studies focusing on the constituents of olive oil and the likely health properties of these constituents;
- (v) Prospective cohort studies in Mediterranean or non-Mediterranean countries directly assessing the effects of the Mediterranean diet, and inferentially of olive oil, on longevity;
- (vi) Randomized intervention studies

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Clearly, this is a schematic classification and many studies have characteristics of two or more of these categories. Here we do not attempt a comprehensive review of the many investigations on the issue, but rather draw conclusions concerning the direction they point to. As in many of these studies reference is made to the “Mediterranean diet score”, a brief explanation is required at this stage. To assess peoples’ adherence to the traditional Mediterranean diet, a simple scoring system was devised in the mid-1990s [3]. The Mediterranean diet score characterizes the traditional Mediterranean diet as a diet that has a high consumption of olive oil, vegetables, legumes, fruits, cereals and, in a later revision, fish; regular but moderate ethanol intake, mostly during meals; and low consumption of meat and dairy products. The Mediterranean diet score takes values from 0 (minimal adherence to the traditional Mediterranean diet) to 9 (maximal adherence to the traditional Mediterranean diet) [4]. Other investigators have used more elaborate scores to assess adherence to the Mediterranean diet. Weighted and more complex scoring schemes are likely to be more discriminatory, but this comes at the cost of simplicity and general applicability of the instrument.

2.1 Ecological studies

Ancel Keys and the collaborators of the classic Seven Countries study [5] reported findings that were mostly focused on the role of diet on coronary heart disease. The ecological associations were interpreted as indicating that the balance between saturated animal fats and unsaturated vegetable lipids (mostly olive oil) could largely account for the variation in the incidence of coronary heart disease. Similar ecological evidence has been invoked by Trichopoulou and her colleagues [6] who argued that the Mediterranean diet, characterized by high consumption of olive oil, is inversely associated with total cancer mortality. Ecological evidence is mostly used for hypothesis generation rather than documentation but, weak as it is, it suggests that Mediterranean diet driven by olive oil consumption is likely to be beneficial to health and conducive to longevity.

2.2 Case-control studies

Several case-control studies, mostly undertaken, as expected, in Greece, Italy and Spain, have evaluated the role of olive oil on the occurrence of coronary heart disease and certain forms of cancer, including breast cancer and colorectal cancer. The results of these studies have indicated that olive oil and monounsaturated lipids (mostly derived in Mediterranean countries from olive oil) are either beneficial or at least no worse than other forms of lipids for the incidence of these chronic diseases [7–9]. Since these diseases are important contributors to total mortality, the evidence derived from these investigations can be inter-

preted as pointing to a potentially valuable contribution of olive oil in the prevention of premature mortality.

2.3 Epidemiological studies in non-Mediterranean countries

The consumption of olive oil is generally low in non-Mediterranean countries, and it may not be justifiable to equate the effects of monounsaturated lipids, which are also derived from meat and dairy products as well as plant oils, to those of olive oil. Neither is it prudent, however, to consider the effects of olive oil and monounsaturated lipids as independent. Several case control studies have pointed out that monounsaturated lipids tend to reduce, or at least not increase, the incidence of some forms of cancer, notably breast cancer [10], as well as coronary heart disease [11]. Meanwhile, cohort studies evaluating adherence to the Mediterranean dietary pattern in relation to longevity have generated results generally supporting a beneficial effect of Mediterranean-like patterns, even in non-Mediterranean populations [12]. As indicated, the results of these studies may or may not directly address the question of whether olive oil is conducive to longevity but, to the extent that they are, they tend to support the notion that olive oil is beneficial to health.

2.4 Biochemical studies

It has been suggested that the apparent beneficial effect of olive oil and Mediterranean diet in general on health and longevity may be due, at least in part, to their high content of antioxidant compounds that are present abundantly in plant foods, red wine and particularly, virgin olive oil [13, 14]. Many of the constituents present in virgin olive oil, besides the protection they confer to the stability of olive oil towards oxidation, are also implicated in the preservation of the redox homeostasis. Antioxidant compounds in olive oil are shown in Table 1.

As indicated, the stability and health promoting properties of olive oil have been attributed to its fatty acid composition (high in MUFA), as well as to its content in antioxidant compounds.

2.5 Prospective cohort studies

Prospective cohort studies undertaken in Mediterranean countries have shown that adherence to the Mediterranean diet is associated with lower overall mortality and thus longevity [4]. Even in non-Mediterranean countries adherence to Mediterranean dietary patterns is associated with longevity [12, 15]. In some studies, olive oil itself has been found to be inversely associated with arterial blood pressure [16], better blood lipid profile [11] and longer survival of diabetics [17]. These studies are limited in number, but they provide the strongest evidence that olive oil and the olive oil-centered Mediterranean diet may contribute to longevity.

Table 1. Compounds with antioxidant activity reported to be present in olive oil

Chemical Class	Subclass	Compound
Phenolic compounds	Phenolic acids	4-Hydroxybenzoic acid, protocatechuic acid, gallic acid, vanillic acid, syringic acid, 4-hydroxyphenylacetic acid, homovanillic acid, <i>o</i> -coumaric acid, <i>p</i> -coumaric acid, caffeic acid, ferulic acid, sinapic acid
	Tyrosol, hydroxytyrosol and derivatives	Tyrosol, hydroxytyrosol, oleuropein, oleuropein aglycon, dialdehyde form of oleuropein aglycon, decarboxymethyl form of oleuropein aglycon, ligstroside aglycon
	Lignans	(+)-Pinoresinol, (+)-1-acetoxypinoresinol
	Flavonoids	Apigenin, luteolin, quercetin
	Closely related non-phenolic compounds	Elenolic acid, cinnamic acid
Hydrocarbons	Triterpenes	Squalene
Chlorophylls	Chlorophyll and Derivatives	Pheophytin α , pheophytin b, chlorophyll α , chlorophyll b, pyropheophytin α
Carotenoids	Carotenes (Hydrocarbons)	β -Carotene
	Xanthophylls	Lutein, neoxanthin, violaxanthin, luteoxanthin, antheraxanthin, mutatoxanthin, β -cryptoxanthin
Tocopherols	–	α , β , γ , and δ -Tocopherol

2.6 Randomized intervention studies

An elegant randomized trial undertaken in Spain has provided powerful evidence that, in comparison with a low-fat diet, a Mediterranean diet rich in olive oil or nuts has beneficial effects on plasma glucose levels, systolic blood pressure, and blood lipid profiles [18]. Several other randomized trials are currently in progress and are expected to provide valuable evidence concerning the effects of olive oil on health and disease, as well as on the intervening physiological processes.

3 Adverse effects of olive oil intake

The obvious criticism for increased olive oil intake stems from the high energy content of this food. The recommendation, however, is not to take olive oil in addition to the usual diet, but rather to substitute olive oil for other lipids and for simple carbohydrates, always aiming at keeping a balance between energy intake and expenditure, preferably at a higher rather than at a lower level. In this context it is of interest that in a study that evaluated an olive oil-rich Mediterranean diet in relation to BMI and waist-to-hip ratio controlling for energy intake, no association of clinical importance was found [19].

4 Conclusion

Several lines of evidence point to olive oil *per se* and the olive oil-centered Mediterranean diet as conducive to better health and longevity. The antioxidant constituents of olive



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oil, as well as its high content in monounsaturated lipids appear to be essential for the apparent beneficial effect of this food.

5 References

- [1] Trichopoulou, A., Lagiou, P., Healthy traditional Mediterranean diet: an expression of culture, history, and lifestyle. *Nutr. Rev.* 1997, 55, 383–389.
- [2] Kipnis, V., Freedman, L. S., Brown, C. C., Hartman, A., *et al.*, Interpretation of energy adjustment models for nutritional epidemiology. *Am. J. Epidemiol.* 1993, 137, 1376–1380.
- [3] Trichopoulou, A., Kouris-Blazos, A., Wahlqvist, M. L., Gnardellis, C., *et al.*, Diet and overall survival in elderly people. *BMJ* 1995, 311, 1457–1460.
- [4] Trichopoulou, A., Costacou, T., Bamia, C., Trichopoulos, D., Adherence to a Mediterranean diet and survival in a Greek population. *N. Engl. J. Med.* 2003, 348, 2599–2608.

- [5] Keys, A., Aravanis, C., Blackburn, H. W., Van Buchem, F. S., *et al.*, Epidemiological studies related to coronary heart disease: characteristics of men aged 40–59 in seven countries. *Acta Med. Scand. Suppl.* 1966, 460, 1–392.
- [6] Trichopoulou, A., Lagiou, P., Kuper, H., Trichopoulos, D., Cancer and Mediterranean dietary traditions. *Cancer Epidemiol. Biomarkers Prev.* 2000, 9, 869–873.
- [7] Martin-Moreno, J. M., Willett, W. C., Gorgojo, L., Banegas, J. R., *et al.*, Dietary fat, olive oil intake and breast cancer risk. *Int. J. Cancer* 1994, 58, 774–780.
- [8] Tzonou, A., Kalandidi, A., Trichopoulou, A., Hsieh, C. C., *et al.*, Diet and coronary heart disease: a case-control study in Athens, Greece. *Epidemiology* 1993, 4, 511–516.
- [9] Braga, C., La Vecchia, C., Franceschi, S., Negri, E., *et al.*, Olive oil, other seasoning fats, and the risk of colorectal carcinoma. *Cancer* 1998, 82, 448–453.
- [10] Wolk, A., Bergstrom, R., Hunter, D., Willett, W., *et al.*, A prospective study of association of monounsaturated fat and other types of fat with risk of breast cancer. *Arch. Intern. Med.* 1998, 158, 41–45.
- [11] Katan, M. B., Zock, P. L., Mensink, R. P., Dietary oils, serum lipoproteins, and coronary heart disease. *Am. J. Clin. Nutr.* 1995, 61(6 Suppl), 1368S–1373S.
- [12] Lagiou, P., Trichopoulos, D., Sandin, S., Lagiou, A., *et al.*, Mediterranean dietary pattern and mortality among young women: a cohort study in Sweden. *Br. J. Nutr.* 2006, 96, 384–392.
- [13] Carluccio, M. A., Siculella, L., Ancora, M. A., Massaro, M., *et al.*, Olive oil and red wine antioxidant polyphenols inhibit endothelial activation: antiatherogenic properties of Mediterranean diet phytochemicals. *Arterioscler. Thromb. Vasc. Biol.* 2003, 23, 622–629.
- [14] Trichopoulou, A., Vasilopoulou, E., Lagiou, A., Mediterranean diet and coronary heart disease: are antioxidants critical? *Nutr. Rev.* 1999, 57, 253–255.
- [15] Trichopoulou, A., Orfanos, P., Norat, T., Bueno-de-Mesquita, B., *et al.*, Modified Mediterranean diet and survival: EPIC-elderly prospective cohort study. *BMJ.* 2005, 330, 991–997.
- [16] Psaltopoulou, T., Naska, A., Orfanos, P., Trichopoulos, D., *et al.*, Olive oil, the Mediterranean diet, and arterial blood pressure: the Greek European Prospective Investigation into Cancer and Nutrition (EPIC) study. *Am. J. Clin. Nutr.* 2004, 80, 1012–1018.
- [17] Trichopoulou, A., Psaltopoulou, T., Orfanos, P., Trichopoulos, D., Diet and physical activity in relation to overall mortality amongst adult diabetics in a general population cohort. *J. Intern. Med.* 2006, 259, 583–591.
- [18] Estruch, R., Martinez-Gonzalez, M. A., Corella, D., Salas-Salvado, J., *et al.*, Effects of a Mediterranean-style diet on cardiovascular risk factors: a randomized trial. *Ann. Intern. Med.* 2006, 145, 1–11.
- [19] Trichopoulou, A., Naska, A., Orfanos, P., Trichopoulos, D., Mediterranean diet in relation to body mass index and waist-to-hip ratio: the Greek European Prospective Investigation into Cancer and Nutrition Study. *Am. J. Clin. Nutr.* 2005, 82, 935–940.