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Original Research Article

Changes in olive oil consumption and long-term body weight changes in 3 United States prospective cohort studies

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A B S T R A C T

Background: Olive oil intake is inversely associated with risk of cardiometabolic diseases. However, its energy density has raised concerns about weight gain.

Objective: To examine the associations between long-term changes in olive oil consumption and changes in body weight in three prospective cohort studies.

Methods: We examined data from 121,119 females and males from the Nurses' Health Study (NHS, 1990–2010), NHSII (1991–2015), and Health Professionals Follow-up Study (HPFS, 1990–2014), aged 65 y or younger and who were free from chronic disease at baseline. We assessed the associations between changes in olive oil intake within each 4-y interval and concurrent body weight changes using multivariable linear regression models. Results across the 3 cohorts were pooled using inverse-variance weights.

Results: At baseline, the mean body mass index (BMI in kg/m^2) was between 25.9 and 26.1 across the 3 cohorts. The mean weight change over each of the 4-y follow-up cycles was highest in the NHSII (1.8 kg; 95% CI [confidence interval]: –6.8, 11.3 kg), followed by the NHS (1.2 kg; 95% CI: –6.8, 9.1 kg), and lastly the health professionals follow-up study HPFS (0.9 kg; 95% CI: −5.4, 7.3 kg). After multivariable adjustment, each ½ tablespoon (7 g) serving per day increment in olive oil consumption was inversely associated with body weight (β coefficient: –0.09 kg, 95% CI: –0.11, –0.08 kg; $P <$ 0.0001). In contrast, each 7 g serving per day increase in other types of added fat (vegetable oils, butter, and margarine) was positively associated with changes in body weight. Results were consistent in stratified analyses by age and BMI. In substitution analyses, replacing margarine, butter, and other vegetable oils with equal amounts of olive oil was associated with less weight gain.

Conclusions: A long-term increase in olive oil intake was inversely associated with body weight in middle-aged adults in the United States. Conversely, increased consumption of other added fats, such as butter and margarine, was positively associated with body weight.

Keywords: olive oil, plant oils, weight change, nurses' health study, health professionals follow-up study

Abbreviations: AHEI, alternative healthy eating index; CI, confidence interval; CVD, cardiovascular diseases; HPFS, Health Professionals Follow-up Study; NHS, Nurses' Health Study; PREDIMED, PREvención con DIeta MEDiterránea.

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Introduction

The global obesity epidemic continues to escalate despite various public health initiatives aimed at weight loss and prevention [1]. The role of dietary fats in weight gain and obesity remains controversial, with low-fat diets still being widely promoted. Fat quality may matter more than fat quantity. Current recommendations highlight the importance of dietary patterns, including healthy sources of dietary fats, particularly those high in unsaturated fatty acids and low in saturated fatty acids (SFA), for preventing cardiometabolic diseases, including obesity [2]. Olive oil, traditionally used as the main source of fat in Mediterranean countries, is rich in monounsaturated fatty acids (MUFA), particularly oleic acid, and contains polyphenols and other antioxidants that contribute to its anti-inflammatory and antioxidant properties [3]. Both experimental studies and clinical trials have demonstrated the benefits of olive oil consumption for the prevention of coronary artery disease, type 2 diabetes, and related risk factors [3,4]. Furthermore, observational studies, including our prior investigations within the Nurses' Health Study (NHS) and the Health Professionals Follow-up Study (HPFS) and results from other cohort studies, have shown that olive oil intake is inversely associated with risk of type 2 diabetes, cardiovascular disease (CVD), and cause-specific and total mortality [5–10].

Despite olive oil being calorie-dense due to its high-fat content and a common belief that increased consumption may lead to weight gain, there is a lack of scientific evidence supporting an association between olive oil and weight gain. Indeed, findings from the PREvención con DIeta MEDiterránea (PREDIMED) trial showed that higher olive oil intake in the context of an unrestricted caloric Mediterranean diet was not associated with weight gain or higher waist circumference [11]. However, no large, long-term prospective studies have examined the relation of higher olive oil consumption with long-term body weight changes in United States adults. Given that recent or current diets are likely more relevant to body weight and that baseline weights may have reached a steady state with the current diet, repeated assessments of diet and analyses of concurrent changes in diet and body weight may provide better insights into nutritional strategies for preventing weight gain. Additionally, prior research in this context has not considered changes in body weight by considering food substitutions, which could lead to more practical dietary advice.

The purpose of this study was to evaluate the relationship between changes in olive oil consumption and long-term body weight changes among middle-aged females and males in 3 United States cohorts over 20–24 y. We hypothesized that higher olive oil intake – within the range of typical consumption of a United States population – is not associated with long-term body weight gain.

Methods

Study design and population

The NHS, NHSII, and HPFS prospective cohorts enrolled 121,700 females (age 30–55 y) in 1976, 116,429 females (25–42 y) in 1989, and 51,529 males (40–75 y) in 1986, respectively [12,13]. Participants in all the cohorts completed self-administered questionnaires on personal characteristics, medical history, lifestyle, and other health-related characteristics at baseline, and this information is updated every 2–4 y.

For the current analysis, the baseline was the year in which olive oil consumption was first included as part of the food frequency questionnaires (FFQ): 1990 for the NHS and HPFS and 1991 for the NHSII. Participants were excluded if they were older than 65 y (because subsequent weight loss may represent unintentional decreases in lean mass rather than body fat loss) and if they reported any of these conditions before baseline: diabetes, cancer, CVD, respiratory disease, chronic kidney disease, neurodegenerative disorders, gastric conditions, and systemic lupus erythematosus. We also excluded those with missing data on diet or body weight and those who reported implausible energy intakes (<600 or >3500 kcal/d for females; <800 or >4200 kcal/d for males). During follow-up, pregnant females, deceased participants, those lost to follow-up, reaching the age of 65, or diagnosed with diabetes were censored at the time of the reported diagnosis, and the following 4-y cycles were not included in the analysis. Participants with the other above-mentioned diseases included as baseline exclusions were censored 6 y before diagnosis. The final analyses included 39,113 females in the NHS, 65,425 females in the NHSII, and 16,581 males in the HPFS.

The protocol was approved by the institutional review board of Brigham and Women's Hospital and Harvard T.H. Chan School of Public Health. All participants gave informed consent.

Dietary assessment

Dietary intake was measured using a validated semiquantitative FFQ with over 130 items, repeatedly administered every 4 y. The reproducibility and validity of these FFQs have been described in previous reports [14,15]. Participants were asked how often, on average, they had consumed specific foods, as well as types of fats, oils, and brands or types of oils used for cooking and added to the table in the preceding year. Total olive oil intake was calculated from the sum of 3 items in the questionnaire related to the consumption of olive oil: olive oil used for salad dressings, olive oil added to food or bread, and olive oil used for baking and frying at home. One tablespoon was equivalent to 13.5 g of olive oil. Total vegetable oil was based on corn, safflower, soybean, and canola oil. The intake of subtype vegetable oils (corn, safflower, soybean, and canola) was estimated based on the reported oil brand and type of fat used for various cooking methods, including frying, sautéing, baking, and salad dressing, and all the food composition data for calculating oil intakes were updated every 4 y. Total margarine was calculated based on the reported frequency of stick, tub, or soft margarine consumption and the amount of margarine added from baking and frying at home. The consumption of butter was calculated in the same manner. Intakes of dairy and other fats and nutrients were calculated based on the Harvard University Food Composition Database [16] and our biochemical analyses. In previous validation studies in these cohorts, the Pearson correlation coefficients comparing responses in the FFQ with 7-d dietary records were 0.67 for total fat, 0.69 for SFAs, 0.57 for polyunsaturated fatty acids (PUFA), and 0.56 for MUFAs [17].

Body weight change

The outcome of weight change was derived from self-reported body weight at baseline and biennially. In previous validation studies, the Spearman correlation coefficient was 0.96, comparing self-reported body weight with weight measured in person by staff [18].

Covariates

Every 2 y, participants returned a mailed validated questionnaire that obtained updated information on age, smoking status, physical activity, medications use, multivitamin use, menopausal and postmenopausal hormone use in females, sleep duration, hours of watching television, physician diagnosis of chronic diseases, and other covariates. Ethnicity and ancestry information was collected in 1986 for males and in 1992 for females. The self-reported categories for ethnicity included White, Black or African American, Asian, American/Indian/Alaska Native, Native Hawaiian/Pacific Islander, or other. For ancestry, the self-reported categories in the questionnaire included Southern European/Mediterranean, Caucasian/Scandinavian, other Caucasian, African American, Hispanic, Asian, American Indian, and other. Because the data on race and ethnicity in our cohorts were collected >30 y ago, they were not consistent with the current standard classifications.

Statistical analysis

We calculated changes in olive oil intake and change in body weight as the difference between baseline and follow-up for each 4-y interval, with a total follow-up period of 20 y in the NHS (1990–2010) and 24 y in the NHSII (1991–2015) and in the HPFS (1990–2014). Multivariable generalized linear regression models with an unstructured correlation matrix and robust variance accounting for within-person repeated measures were used, with change in body weight as the dependent variable. Both intake and outcome were analyzed as continuous variables, and outliers were truncated at the 0.5th and 99.5th centiles. Missing covariate data were handled with a missing indicator for categorical variables, and the last value was carried forward for continuous variables.

In multivariable models, we adjusted for theory-based and previously described in the literature variables including age, questionnaire cycle (4-y intervals), ethnicity (White, Black, other), socioeconomic status index (continuous), smoking status (baseline and 4-y changes) (stay never smoker, stay former smoker, stay current smoker, change from former to current smoker, change from never to current smoker, change from current to former smoker), alcohol intake (baseline and 4-y changes; continuous), physical activity (baseline and 4-y changes; continuous), television watching [baseline and 4-y changes; continuous; baseline only in NHS and NHSII (0–1, 2–5, 6–20, 21–40, >40 h/wk)], BMI (baseline; continuous), sleep duration (baseline and 4-y changes; ≤6, 7, 8, >8 h/d) in each 4-y interval. In the first model, we did not adjust for changes in total energy intake because it may mediate the associations of olive oil with body weight change. In a second model, we adjusted for baseline and 4-y changes in total energy intake (kilocalories/day; continuous) and dietary factors (fruits, vegetables, red and processed meat, sugar-sweetened beverages, coffee, and refined grains; continuous). Finally, in sensitivity analyses, we adjusted the last model for baseline and 4-y changes of the alternative healthy eating index (AHEI) (without alcohol and PUFA; continuous) [19]. In other sensitivity analyses, we excluded BMI from the models. We conducted similar analyses using other types of added fats, including butter, margarine, and other vegetable oils (including sunflower, corn, safflower, and soybean).

Effect modification was also examined according to BMI category (<25, 25–30, and ≥30), age (<50 y, ≥50 y), AHEI (above or below the median), and South European ancestry (yes or no) for olive oil and other types of added fat intake. Wald *P* values for interactions were calculated by adding a multiplicative interaction term between an ordinal subgroup variable and the change in olive oil intake.

We also performed substitution models to evaluate the association of substituting different types of added fat (butter, margarine, and other vegetable oils) and refined grains with olive oil intake, with concurrent changes in weight. To estimate the substitutions, we included continuous changes in intake for the 2 foods simultaneously in the same multivariable model, which also contained total energy intake and other covariates. We then calculated the difference between the β coefficients; variances and covariance were used to estimate the 95% CI.

All analyses were performed with SAS version 9.4 in each cohort and then pooled through fixed-effect meta-analysis. We used a 2-sided $\alpha < 0.05$ for statistical significance.

Results

Descriptive characteristics

The characteristics of baseline and average 4-y changes of participants in NHS, NHSII, and HPFS are summarized in Table 1. At baseline, the mean age ranged from 45 in NHS to 57 y in HPFS. Mean BMI across cohorts ranged from 25.9 to 26.1. Over each 4-y follow-up cycle, average weight change was highest in NHSII (1.8 kg; 95% CI [confidence intervals]: –6.8, 11.3 kg), followed by NHS (1.2 kg; 95% CI: –6.8, 9.1 kg) and HPFS (0.9 kg; 95% CI: –5.4, 7.3 kg). At baseline, the average intake of olive oil was 3.3 g/d in NHS, 3.9 g/d in NHSII, and 3.0 g/d in HPFS. The average change in olive oil consumption overall 4-y periods was 1.3 g/d in NHS and 1.0 g/d in both NHSII and HPFS. Intake of other vegetable oils, mayonnaise, and margarine showed smaller increases, whereas butter consumption remained largely stable.

Changes in olive oil and added fat consumption

Table 2 presents the average 4-y body weight changes associated with changes in olive oil consumption. An increase of ½ tablespoon (7 g) servings per day of olive oil was inversely associated with body weight (multivariable-adjusted model: –0.09 kg; 95% CI: –0.11, –0.08 kg) after adjusting for sociodemographic and dietary variables at baseline and 4-y changes in the pooled analysis of the 3 cohorts. Results remained consistent when we further adjusted for other fats (Supplemental Table 1) but were attenuated when the final models were adjusted for the AHEI instead of specific dietary variables (Supplemental Table 2).

Table 3 shows the relationship between changes in intake of other added fats, including vegetable oils, butter, margarine, and weight changes in the 3 cohorts. In the pooled analysis of the 3 cohorts, an increase of 7 g/d of other vegetable oils (model 2: 0.16 kg; 95% CI: 0.13, 0.20 kg) and butter (model 2: 0.37 kg; 95% CI: 0.32, 0.41 kg) was positively associated with body weight. The 4-y weight changes associated with changes in margarine intake were minimal (model 2: 0.07 kg; 95% CI: 0.06, 0.08 kg). Margarine findings were further stratified by periods before and after the *trans*-fat ban, showing minimal changes in weight before 2000 (Supplemental Table 3). No significant associations were found between margarine and weight change after the year 2000. Consistent with the olive oil analyses, the results of other fats and weight changes remained consistent when the models were mutually adjusted for other fats (Table 3) and attenuated when the models were adjusted for overall diet quality (AHEI) (Supplemental Table 4). The results for changes in olive oil and other fats and changes in body weight were consistent when BMI was excluded from the models (Supplemental Table 5).

Subgroup analyses

Stratification analyses for several variables, including baseline age, BMI, AHEI, South European ancestry, and refined grains intake, are shown in Figure 1 and Supplemental Table 6. Analyses stratified by age showed stronger results for olive oil in adults aged ≤50 y and stronger for other types of fat consumption in people aged >50 y. Associations

TABLE 1
Baseline characteristics and average 4-y changes in 3 prospective cohorts[1].

Characteristic	Nurses' Health Study (N = 39,113)		Nurses' Health Study II (N = 65,425)		Health Professionals Follow-up Study (N = 16,581)	
	Baseline	Changes within each 4-y period	Baseline	Changes within each 4-y period	Baseline	Changes within each 4-y period
Age (year)	57.0 ± 5.6	/	45.6 ± 7.9	/	56.1 ± 6.1	/
Weight (kg)	70.3 ± 14.0	1.2 (–6.8 to 9.1)	70.5 ± 16.2	1.8 (–6.8 to 11.3)	83.6 ± 12.4	0.9 (–5.4 to 7.3)
BMI (kg/m^2)	26.1 ± 4.9	0.4 (–2.4 to 3.4)	25.9 ± 5.7	0.7 (–2.6 to 4.2)	26.0 ± 3.4	0.3 (–1.7 to 2.2)
Physical activity (Met-h/wk)	20.2 ± 23.6	–0.1 (–29.8 to 29.8)	21.1 ± 26.3	1.5 (–30.2 to 36.0)	34.2 ± 31.1	1.3 (–44.2 to 49.5)
Total daily sleep (h/d)	7.0 ± 0.6	/	7.0 ± 0.9	/	7.0 ± 0.8	/
Television watching (h/wk)	2.8 ± 0.8	/	2.5 ± 0.8	/	9.1 ± 6.4	0.2 (–10.0 to 10.5)
Total calorie intake (kcal/d)	1764 ± 511	1.5 (–701 to 705)	1800 ± 558	–0.5 (–764 to 763)	1996 ± 604	28.9 (–749 to 822)
Alcohol intake (g/d)	5.6 ± 9.5	0.3 (–6.7 to 8.7)	4.8 ± 8.5	0.7 (–5.2 to 8.7)	11.6 ± 14.8	1.0 (–11.2 to 15.8)
Olive oil intake (g/d)	3.3 ± 6.3	1.3 (–6.0 to 11.8)	3.9 ± 6.9	1.0 (–6.7 to 11.1)	3.0 ± 5.9	1.0 (–5.8 to 10.7)
Other vegetable oils[2] (g/d)	3.6 ± 3.9	–0.5 (–6.8 to 5.1)	3.0 ± 3.4	–0.3 (–5.5 to 4.4)	3.7 ± 3.9	–0.3 (–6.2 to 5.2)
Total fat intake (g/d)	60.2 ± 23.0	–0.7 (–32.8 to 31.5)	63.4 ± 24.5	–1.1 (–33.1 to 36.6)	68.6 ± 27.7	–1.3 (–33.8 to 38.1)
MUFAs	23.4 ± 9.5	–0.2 (–13.7 to 13.7)	24.2 ± 9.7	0.5 (–13.4 to 15.0)	27.0 ± 11.3	0.5 (–14.4 to 16.1)
PUFAs	11.2 ± 4.9	0.1 (–7.1 to 7.7)	11.9 ± 5.2	0.7 (–6.6 to 8.6)	13.3 ± 5.7	0.6 (–7.1 to 9.0)
SFAs	19.8 ± 8.0	–0.7 (–11.8 to 10.1)	20.9 ± 8.2	–0.2 (–11.9 to 11.5)	22.0 ± 9.4	0.1 (–11.8 to 11.9)
Fat-containing foods (g/d)						
Butter intake	1.6 ± 3.3	0.2 (–3.7 to 4.8)	1.5 ± 2.8	0.2 (–3.0 to 3.8)	1.6 ± 3.3	0.1 (–3.3 to 4.0)
Margarine	10.5 ± 14.9	–2.2 (–33.6 to 14.0)	6.2 ± 10.7	–1.6 (–15.0 to 8.6)	8.1 ± 13.1	–1.4 (–15.0 to 9.3)
Mayonnaise intake	0.1 ± 0.5	–0.01 (0 to 0)	0.03 ± 0.5	–0.01 (–0 to 0)	4.4 ± 6.5	0.1 (–8.6 to 8.6)
Nuts	4.0 ± 8.7	1.2 (–8.1 to 14.0)	5.2 ± 11.1	1.5 (–10.1 to 19.9)	7.2 ± 12.6	1.4 (–14.0 to 22.1)
Food groups (servings/d)						
Sugar-sweetened beverages	0.2 ± 0.5	–0.003 (–0.6 to 0.6)	0.3 ± 0.7	–0.03 (–0.8 to 0.5)	0.3 ± 0.6	–0.01 (–0.8 to 0.7)
Coffee intake	2.1 ± 1.6	–0.2 (–2.1 to 1.6)	1.5 ± 1.5	–0.02 (–1.9 to 1.6)	1.7 ± 1.7	–0.1 (–2.4 to 2.0)
Refined grains	1.6 ± 1.1	–0.1 (–1.9 to 1.6)	1.5 ± 1.0	–0.1 (–1.6 to 1.3)	1.6 ± 1.3	–0.1 (–2.1 to 1.8)
Whole grains	1.4 ± 1.3	–0.04 (–2.1 to 1.9)	1.4 ± 1.2	–0.03 (–1.9 to 1.7)	1.2 ± 1.1	0.1 (–1.8 to 2.2)
Red and processed meats	0.8 ± 0.6	–0.1 (–0.9 to 0.7)	0.8 ± 0.6	–0.02 (–0.9 to 0.8)	1.0 ± 0.8	–0.03 (–1.1 to 1.0)
Fruits and vegetables	6.1 ± 3.2	0.5 (–6.0 to 6.1)	5.3 ± 3.0	0.2 (–4.8 to 5.4)	4.8 ± 2.4	–0.1 (–3.2 to 2.9)
AHEI score	43.9 ± 10.6	1.4 (–11.6 to 14.9)	44.5 ± 12.1	2.5 (–10.4 to 17.0)	44.3 ± 11.1	1.8 (–9.7 to 14.1)

Abbreviations: AHEI, alternative healthy eating index; BMI, body mass index; MET, metabolic equivalent of task; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; SD, standard deviation; SFA, saturated fatty acid; Met.

[1] Plus-minus values are means ± SD for baseline and means (fifth to 95th percentile values) for changes.

[2] Other vegetable oils include corn, canola, safflower, and soybean oils. Data are based on 20 y of follow-up (1990–2010) in the Nurses' Health Study (NHS), 24 y of follow-up (1991–2015) in the NHS II, and 24 y of follow-up (1990–2014) in the Health Professionals Follow-up Study. The score excludes the PUFA ratio and alcohol intake.

TABLE 2
Changes in olive oil intake and body weight changes in 3 prospective cohorts.

	Age-adjusted Model β estimate (95% CI)	P value	Multivariable-adjusted Model 1 β estimate (95% CI)	P value	Multivariable-adjusted Model 2 β estimate (95% CI)	P value
Nurses' Health Study	–0.03 (–0.07, 0.001)	0.05	–0.03 (–0.07, 0.004)	0.08	–0.05 (–0.08, –0.01)	0.01
Nurses' Health Study II	–0.10 (–0.13, –0.08)	<0.0001	–0.10 (–0.12, –0.07)	<0.0001	–0.12 (–0.14, –0.09)	<0.0001
Health Professionals Follow-up Study	–0.07 (–0.12, –0.03)	0.003	–0.08 (–0.13, –0.03)	0.001	–0.10 (–0.15, –0.05)	0.0002
Pooled	–0.08 (–0.10, –0.06)	<0.0001	–0.08 (–0.10, –0.06)	<0.0001	–0.09 (–0.11, –0.08)	<0.0001

Per 7 g (0.5 tablespoon) serving.
The baseline for Nurses' Health Study is 1990 (20 y of follow-up until 2010), Nurses' Health Study II is 1991 (24 y of follow-up until 2015), and Health Professionals Follow-up Study is 1990 (24 y of follow-up until 2014).
Model 1 was adjusted for age (continuous), questionnaire cycle (4-y intervals), ethnicity (White, Black, other), socioeconomic status index (continuous), smoking status (baseline and 4-y changes; stay never smoker, stay former smoker, stay current smoker, change from former to current smoker, change from never to current smoker, change from current to former smoker), alcohol intake (baseline and 4-y changes; continuous), physical activity (baseline and 4-y changes; continuous), television watching (baseline and 4-y changes; continuous; baseline only in Nurses' Health Study and Nurses' Health Study II), BMI (baseline; continuous), sleep duration (baseline and 4-y changes; ≤6, 7, 8, >8 h/d).
Model 2 was adjusted for model 1 variables and baseline and 4-y changes of total energy intake (kilocalories/day; continuous) and dietary factors (fruits, vegetables, red and processed meat, sugar-sweetened beverages, coffee, refined grains; continuous).
Abbreviations: BMI, body mass index, CI, confidence interval.

between changes in olive oil intake or other added fats with weight changes were stronger among people with overweight or obesity at baseline, compared with those with normal weight. These findings were consistent in analyses within the individual cohorts.

Substitution analyses

In substitution analyses, replacing 0.5 tablespoon/day of other added fats with olive oil was inversely associated with body weight [–0.52 (95% CI: –0.57, –0.47), –0.18 (95% CI: –0.20, –0.16), and

TABLE 3
Changes in vegetable oils, butter, and margarine intake and body weight changes in 3 prospective cohorts.

	Age-adjusted Model β estimate (95% CI)	Multivariable-adjusted Model 1 β estimate (95% CI)	Multivariable-adjusted Model 2 β estimate (95% CI)	Multivariable-adjusted Model 3 β estimate (95% CI)
Vegetable oils				
Nurses' Health Study	0.32 (0.26, 0.38)	0.31 (0.24, 0.37)	0.20 (0.14, 0.26)	0.18 (0.12, 0.25)
Nurses' Health Study II	0.35 (0.30, 0.40)	0.36 (0.31, 0.41)	0.16 (0.11, 0.21)	0.13 (0.08, 0.19)
Health Professionals Follow-up Study	0.19 (0.12, 0.26)	0.19 (0.12, 0.27)	0.12 (0.05, 0.19)	0.11 (0.04, 0.19)
Pooled	0.31 (0.27, 0.34)	0.31 (0.27, 0.34)	0.16 (0.13, 0.20)	0.15 (0.11, 0.18)
Butter				
Nurses' Health Study	0.52 (0.45, 0.60)	0.51 (0.44, 0.59)	0.43 (0.35, 0.50)	0.47 (0.40, 0.55)
Nurses' Health Study II	0.58 (0.51, 0.64)	0.56 (0.50, 0.62)	0.38 (0.32, 0.44)	0.41 (0.35, 0.47)
Health Professionals Follow-up Study	0.28 (0.18, 0.38)	0.28 (0.18, 0.38)	0.22 (0.12, 0.32)	0.25 (0.15, 0.35)
Pooled	0.50 (0.46, 0.55)	0.49 (0.45, 0.53)	0.37 (0.32, 0.41)	0.40 (0.36, 0.44)
Margarine				
Nurses' Health Study	0.10 (0.08, 0.11)	0.09 (0.08, 0.11)	0.08 (0.06, 0.09)	0.09 (0.07, 0.10)
Nurses' Health Study II	0.11 (0.09, 0.12)	0.11 (0.09, 0.13)	0.07 (0.06, 0.09)	0.08 (0.07, 0.10)
Health Professionals Follow-up Study	0.07 (0.05, 0.09)	0.07 (0.05, 0.09)	0.05 (0.03, 0.08)	0.06 (0.04, 0.08)
Pooled	0.10 (0.09, 0.11)	0.10 (0.09, 0.11)	0.07 (0.06, 0.08)	0.08 (0.07, 0.09)

Per 7 g (0.5 tablespoon) serving.
Vegetable oils include corn, canola, safflower, and soybean oils.
Weight changes in kilograms.
Model 1 was adjusted for age (continuous), questionnaire cycle (4-y intervals), ethnicity (White, Black, other), socioeconomic status index (continuous), smoking status (baseline and 4-y changes; stay never smoker, stay former smoker, stay current smoker, change from former to current smoker, change from never to current smoker, change from current to former smoker), alcohol intake (baseline and 4-y changes; continuous), physical activity (baseline and 4-y changes; continuous), television watching (baseline and 4-y changes; continuous; baseline only in Nurses' Health Study and Nurses' Health Study II), BMI (baseline; continuous), sleep duration (baseline and 4-y changes; ≤6, 7, 8, >8 h/d).
Model 2 was adjusted for model 1 variables and baseline and 4-y changes of total energy intake (kilocalories/day; continuous) and dietary factors (fruits, vegetables, red and processed meat, sugar-sweetened beverages, coffee, refined grains; continuous).
Model 3 was adjusted for model 2 variables, baseline and 4-y changes in olive oil, and mutually adjusted for baseline and 4-y changes of other vegetable oils, butter, and margarine.
Abbreviations: BMI, body mass index, CI, confidence interval.

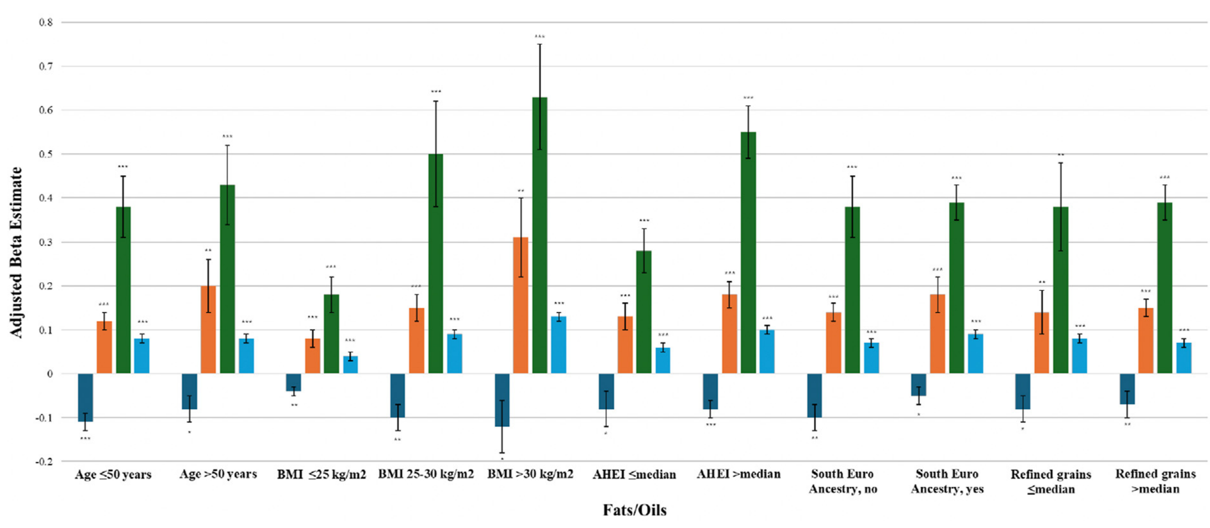

FIGURE 1. Figure 1 shows the pooled subgroup analyses for the relationship between changes in the intake of olive oil, vegetable oils, butter, and margarine and body weight changes in 3 prospective cohorts. *P* value = *<0.05, **<0.01, ***<0.0001. The units are per 7 g (0.5 Tablespoon) serving. Vegetable oils include corn, canola, safflower, and soybean oils. Weight changes are in kilograms. A multivariable model was adjusted for: age (continuous), questionnaire cycle (4-y intervals), ethnicity (White, Black, other), socioeconomic status index (continuous), smoking status (baseline and 4-y changes; stay never smoker, stay former smoker, stay current smoker, change from former to the current smoker, change from never to current smoker, change from current to a former smoker), alcohol intake (baseline and 4-y changes; continuous), physical activity (baseline and 4-y changes; continuous), television watching (baseline and 4-y changes; continuous; baseline only in NHS and NHSII), BMI (baseline; continuous), sleep duration (baseline and 4-y changes; ≤6, 7, 8, >8 h/d), baseline and 4-y changes of total energy intake (kilocalories/day; continuous), and baseline and 4-y changes of dietary factors (fruits, vegetables, red and processed meat, sugar-sweetened beverages, coffee, refined grains; continuous). AHEI, Alternative Healthy Eating Index; BMI, body mass index.

TABLE 4
Association of substituting different types of oils and fats with olive oil and body weight changes in 3 prospective cohorts.

	Margarine		Butter		Vegetable oils		Carbohydrate	
	β estimate (95% CI)	*P* value	**β estimate (95% CI)**	*P* value	**β estimate (95% CI)**	*P* value	**β estimate (95% CI)**	*P* value
Nurses' Health Study	–0.13 (–0.16, –0.09)	<0.0001	–0.53 (–0.61, –0.44)	<0.0001	–0.14 (–0.20, –0.07)	<0.0001	–0.06 (–0.09, –0.02)	0.003
Nurses' Health Study II	–0.22 (–0.25, –0.19)	<0.0001	–0.58 (–0.64, –0.51)	<0.0001	–0.17 (–0.22, –0.12)	<0.0001	–0.14 (–0.16, –0.12)	<0.0001
Health Professionals Follow-up Study	–0.14 (–0.19, –0.08)	<0.0001	–0.35 (–0.46, –0.24)	<0.0001	–0.19 (–0.28, –0.11)	<0.0001	–0.09 (–0.14, –0.04)	0.0003
Pooled	-0.18 (–0.20, –0.16)	<0.0001	–0.52 (–0.57, –0.47)	<0.0001	–0.16 (–0.20, –0.13)	<0.0001	–0.11 (–0.13, –0.09)	<0.0001

Per 7 g (0.5 tablespoon) serving.
Weight changes in kilograms.
Vegetable oils include corn, canola, safflower, and soybean oils.
Carbohydrate considers all carbohydrate sources in grams/day.
A Multivariable model was adjusted for age (continuous), questionnaire cycle (4-y intervals), ethnicity (White, Black, other), socioeconomic status index (continuous), smoking status (baseline and 4-y changes; stay never smoker, stay former smoker, stay current smoker, change from former to current smoker, change from never to current smoker, change from current to former smoker), alcohol intake (baseline and 4-y changes; continuous), physical activity (baseline and 4-y changes; continuous), television watching (baseline and 4-y changes; continuous; baseline only in Nurses' Health Study and Nurses' Health Study II), BMI (baseline; continuous), sleep duration (baseline and 4-y changes; ≤6, 7, 8, >8 h/d), baseline and 4-y changes of total energy intake (kilocalories/day; continuous), and baseline and 4-y changes of dietary factors (fruits, vegetables, red and processed meat, sugar-sweetened beverages, coffee, refined grains; continuous).
Abbreviations: BMI, body mass index, CI, confidence interval.

–0.16 (95% CI: –0.20, –0.13) for butter, margarine, and other vegetable oils, respectively; $P < 0.0001$ for all in pooled analysis] (Table 4). Similarly, replacing 7 g serving per day of carbohydrates with olive oil was inversely associated with body weight [–0.11 (95% CI: –0.13, –0.09)] (Table 4). Results for the different margarine types based on the periods before and after the *trans*-fat ban and by type of grain are shown in Supplemental Table 7, whereby replacing a 7 g serving per day of carbohydrates with olive oil was associated with less weight gain [–0.16 (95% CI: –0.18, –0.14)] and [–0.05 (95% CI: –0.07, –0.03)], respectively. Supplemental Table 8 shows the results of the joint association of changes in intake of olive oil and diet quality at baseline and weight change, where less weight gain was present in adults that jointly consumed more olive oil and were in the highest tertile of diet quality.

Discussion

In three large prospective studies in males and females in the United States, increases in olive oil intake were inversely associated with body weight over time after adjusting for sociodemographic and dietary factors. In contrast, increasing the intake of margarine, other vegetable oils, and butter was positively associated with changes in body weight. Stratified analyses showed that these associations were particularly strong among participants with overweight and obesity at baseline. In substitution models, replacing butter, margarine, other vegetable oils, and refined grains with equal servings of olive oil was associated with less weight gain. Substituting butter for olive oil was strongly inversely associated with body weight. These findings support dietary guidelines emphasizing the importance of fat quality over fat quantity, even within the framework of weight management.

Clinical trials and epidemiological studies have robustly established inverse associations between olive oil intake and cardiometabolic diseases such as type 2 diabetes, CVD, and mortality [3,4,7–9,20]. However, the relationship between olive oil consumption and weight gain remains less clear, particularly in populations beyond the Mediterranean region. Olive oil has been commonly perceived as an energy and fat-dense food, and consequently, its consumption has been believed to promote weight gain. Nevertheless, emerging lines of evidence do not support that belief. In a large-scale study conducted among 7368 participants in a free-living Mediterranean cohort, characterized by large variability in olive oil consumption, no significant associations were found between olive oil intake and weight gain, nor between olive oil consumption and risk of overweight or obesity [21].

Strong evidence comes from the PREDIMED study, where a long-term randomized intervention with an unrestricted-calorie, Mediterranean Diet supplemented with virgin olive oil was associated with no significant difference in body weight and some evidence of less gain in central adiposity compared with a control diet [11]. Specifically, after multivariable adjustment, the difference in 5-y changes in body weight in the group randomly assigned to the Mediterranean diet with extra-virgin olive oil group was −0.41 kg (95% CI: −0.83, 0.01; $P = 0.056$), as compared to the control group randomly assigned to a low-fat diet. Moreover, another study from PREDIMED found that increased dietary energy density over 3 y, driven by higher olive oil and nut consumption, was not associated with weight gain [22]. In line with these results, adherence to the traditional Mediterranean diet, rich in olive oil, was found to be inversely associated with risk of overweight and/or obesity, as well as with 5-y weight gain, according to a systematic review and meta-analysis of prospective cohort studies [23]. As shown in another recent review, 6 randomized controlled trials examined the effects of extra-virgin olive oil on weight loss. The studies showed mixed results, with some randomized controlled trials showing greater body fat loss compared to other fat sources, such as soybean oil, and varying impacts on total energy intake among participants [24].

Our study findings contribute additional evidence suggesting that even in populations outside the Mediterranean region, olive oil consumption may serve as a favorable source of dietary fat without contributing to weight gain over time. Notably, our study revealed inverse associations between olive oil intake and body weight in both male and female participants from the United States. These beneficial associations of olive oil can be attributed to the way these types of fat are used. One potential limitation of our study is the possibility of confounding due to an overall healthier lifestyle among participants who chose olive oil consumption in this population. However, we mitigated this concern by adjusting for several sociodemographic confounders, including socioeconomic status and overall diet quality, and observed minimal attenuation of results after adjustment. Stratified analysis showed associations between individuals with and without South European ancestry, although the results were stronger in the first group.

In substitution analyses, consistent with prior findings indicating that replacing other sources of fat, such as butter, margarine, and other vegetable oils, with olive oil is linked to lower risks of CVD, CVD mortality, and all-cause mortality [6,7], findings from the present study revealed a similar trend: substituting olive oil for butter, vegetable oils, or margarine intake was associated with less weight gain over time. Butter and margarine, often high in saturated and/or *trans* fats, have been implicated in promoting weight gain and adverse effects on metabolic health, whereas olive oil, rich in MUFA and beneficial bioactive compounds, may confer protective effects against excessive weight gain. At the time of the study, most margarines contained considerable concentrations of *trans* fatty acids, which potentially affected the associations. Our results showed no significant associations between margarine and weight change after the year 2000.

Several potential mechanisms may explain the favorable associations of olive oil consumption with less weight gain over time compared to other vegetable oils, butter, and margarine. The rich content of MUFAs, particularly oleic acid, in olive oil appears to play a crucial role in modulating metabolic processes favoring weight management [25]. Prior research from clinical trials has suggested that oleic acid may stimulate thermogenesis, increase total energy expenditure, and enhance feelings of satiety, thus contributing to the regulation of energy balance [26]. Although other vegetable oils, such as canola oil, are also rich in oleic acid, olive oil contains a higher concentration of bioactive compounds that contribute to its health benefits. Additionally, previous studies have shown benefits of MUFA from plant sources but potential harms from animal sources. This distinction may be due to unique bioactive compounds present in plant-based sources or confounding dietary factors, such as higher saturated fat and cholesterol intake from animal sources compared with increased vegetable consumption associated with plant-based MUFA [27,28].

Additionally, olive oil consumption was associated with a reduction in adiposity, particularly abdominal fat, and central obesity, highlighting its potential as a dietary strategy for weight management [11]. Mechanistically, it has been suggested that olive oil-rich diets may activate adenosine monophosphate (AMP)-activated protein kinase signaling, a key regulator of cellular energy metabolism, although also modulating pro-inflammatory pathways and appetite-regulating molecules [25]. Controlled feeding studies of vegetable oils rich in MUFAs, including olive oil, high-oleic-acid sunflower oil, high-oleic acid canola oil, and nuts, have consistently demonstrated beneficial effects on reducing other cardiovascular disease risk factors and improving metabolic health [29]. Finally, adding olive oil to meals can increase the intake of vegetables and make diets more palatable without promoting weight gain [30,31]. However, in low-income populations with very high intake of starch staples, increasing the palatability of diets by the addition of fat could result in weight gain, and in high-income populations, adding olive oil or other types of fat to refined starches to create highly palatable products could have a different effect on weight change than addition olive oil to vegetables as in a Mediterranean-type diet.

Strengths and limitations

Our study has notable strengths, including a large sample size across 3 cohorts, extended follow-up, and repeated measurements with validated questionnaires. Using repeated dietary assessments and validated questionnaires allowed us to assess changes in diet and weight within individuals. This approach provides a more detailed understanding of how diet and weight interact over time. One key limitation is our reliance on self-reported estimates for olive oil intake. Another concern is the possibility of reverse causation, given that weight changes were assessed within the same 4-y intervals as changes in diet. Potential errors in dietary measurement could introduce bias, especially if individuals with higher BMI differentially underreported or overreported their intake. However, we found that controlling for baseline BMI did not significantly impact the results. Moreover, changes in olive intake could be associated with changes in other dietary factors. To mitigate this, we adjusted for baseline and concurrent changes in dietary factors, overall diet quality, and changes in physical activity and other lifestyle behaviors during the same period. We were not able to distinguish among olive oil varieties (i.e., extra-virgin olive oil compared with common olive oil) in this population. However, the effects of different varieties of olive oil on weight gain may be more apparent than for other health outcomes such as cardiovascular health. Additionally, the generalizability of our findings to other populations is limited. However, results are consistent with previous studies in other regions, such as the Mediterranean, and consistent results were observed when stratifying for South European ancestry.

Conclusions and public health implications

Increasing olive oil consumption was inversely associated with long-term body weight among middle-aged adults in the United States. In contrast, higher consumption of other types of added fats—such as other vegetable fats, butter, margarine—and refined grains was associated with increased body weight. These findings suggest that substituting olive oil for other sources of fats may help prevent weight gain. This evidence highlights the potential importance of dietary fat quality and sources for long-term weight control as well as risk of cardiometabolic diseases.

Author contributions

The authors' responsibilities were as follows – MG-F, LSP, FBH: conceived the study idea, designed the research, and analyzed the data; YL, MJS, WCW, FBH: provided statistical expertise and verified the analysis; MG-F, LSP: drafted the manuscript; A-JT: contributed to coding, and conducted a technical review to verify data; MG-F, LSP: had primary responsibility for final content. All authors provided critical revision of the manuscript; and all authors: read and approved the final manuscript.

Conflict of interest

JS-S has a relationship with Rovira i Virgili University, including non-financial support, and MAM-G has a relationship with the University of Navarra, including non-financial support. JS-S and MG-F are the principal investigators of a research grant from the International Nut Council (INC). JS-S and MAM-G received olive oil used in the PREDIMED and PREDIMED-PLUS trials from The Fundaciòn Patrimonio Comunal Olivarero and Hojiblanca SA.

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Data availability

Because of participant confidentiality and privacy concerns, data cannot be shared publicly, and requests to access Nurses' Health Studies (NHS)/Health Professionals Follow-up Study (HPFS) data must be submitted in writing. Further information including the procedures to obtain and access data from the NHS and HPFS, is provided at https://nurseshealthstudy.org/researchers (contact e-mail: nhsaccess@channing.harvard.edu).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajcnut.2025.02.012.

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