ORIGINAL ARTICLE

Association of Mediterranean diet and olive oil intake with type 2 diabetes risk

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ABSTRACT

The Mediterranean Diet (MD) is widely acknowledged for its protective role against chronic non-communicable diseases, including type 2 diabetes mellitus (T2DM). Extra-virgin olive oil (EVOO), the principal fat source of the MD, is considered a key contributor to its cardiometabolic benefits. This cross-sectional study evaluated the associations between adherence to the Mediterranean Diet (MD), olive oil consumption, and estimated risk of type 2 diabetes mellitus (T2DM) in a sample of 375 non-diabetic adults residing in Famagusta, Cyprus. Dietary intake data were collected using validated food-frequency questionnaires. Adherence to the MD was quantified using the Mediterranean Diet Assessment Scale (MEDAS), while the estimated risk of T2DM was determined using the Finnish Diabetes Risk Score (FINDRISC), a validated risk assessment instrument. Overall adherence to the MD was not significantly associated with estimated T2DM risk, as no correlation was observed between MEDAS scores and FINDRISC values. In contrast, higher olive oil consumption was significantly associated with lower T2DM risk scores, whereas greater sunflower oil intake was positively associated with increased T2DM risk. These findings suggest that the type of dietary fat consumed particularly olive oil may exert a more substantial influence on T2DM risk than adherence to the overall MD pattern alone. Prospective, large-scale studies are needed to confirm these associations and clarify the underlying biological mechanisms.

Key words: diabetes, mediterranean diet, mediterranean diet score, olive oil

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Introduction

Diabetes is among the top 10 leading causes of death globally. It is well-established that individuals with diabetes have a 2–3-fold increased risk of all-cause mortality. The presence of diabetes is linked to higher mortality rates from infections, cardiovascular disease, stroke, chronic kidney disease, chronic liver disease, and cancer (1). According to the International Diabetes Federation (IDF), 537 million adults aged 20-79 were living with diabetes in 2021, with projections indicating that this number will rise to 643 million by 2030 and 783 million by 2045 (2). Despite its extensive impact, there is still no definitive cure for the disease. Current treatments primarily focus on alleviating the symptoms associated with diabetes rather than addressing the root cause of the disease (3). Therefore, preventing diabetes is crucial in reducing the overall disease burden for both individuals and governments.

Lifestyle intervention studies have shown a 30-67% relative risk reduction in the development of type 2 diabetes mellitus (T2DM), with sustained long-term reductions in incidence. However, there is a need for the development of standardized lifestyle interventions to further improve their effectiveness (4). The Mediterranean Diet (MD), which is characterized by a high intake of olive oil, vegetables and fruits, whole grains, fish, low-fat dairy products and low red meat consumption (5). Adherence to the MD is associated with significant health benefits, ranging from a reduced risk of mortality to a decreased risk of chronic diseases (5). There is strong evidence indicating that the (MD offers protective benefits against the development of T2DM and is highly effective for managing the disease (6). The protective role of MD is largely attributed to its ability to prevent weight gain and its rich content of beneficial components, including polyphenols and monounsaturated fatty acids (MUFAs) (7, 8). Extra-virgin olive oil (EVOO) is a key component that distinguishes the MD from other dietary patterns. EVOO is rich in monounsaturated fatty acids (MUFAs), unsaponifiable compounds, and hydrophilic phenolic compounds. Notably, phenolic components such as oleuropein, hydroxytyrosol, flavonoids (particularly flavones), and lignans are abundant in EVOO (9). Consumption of EVOO has been associated with favorable outcomes in the prevention, development, and progression of T2DM (9, 10). A sub-study from the PREDIMED study demonstrated a 51% reduction in T2DM incidence in participants following an EVOO-enriched MD compared to those on a low-fat diet, with a median follow-up of 4 years (11). Furthermore, replacing carbohydrates with MUFAs as the primary dietary component in T2DM patients was found to improve their metabolic profile, leading to a reduction in fasting plasma glucose levels (12). The protective role of EVOO in diabetes extends beyond its MUFA content to encompass its rich polyphenol composition. Olive oil polyphenols, particularly hydroxytyrosol, tyrosol, and apigenin, have been shown to support pancreatic beta-cell health by promoting cell proliferation, enhancing insulin biosynthesis, and increasing glucose-stimulated insulin secretion (13). In addition to their effects on beta-cells, the phenolic compounds in EVOO help regulate postprandial hyperglycemia by inhibiting α-amylase and α-glucosidase, enzymes responsible for carbohydrate digestion, thus delaying the absorption of carbohydrates (14, 15).

To the best of our knowledge, no study has specifically examined the association between olive oil consumption, adherence to the MD, and the risk of T2DM in Famagusta. Therefore, this study was conducted to investigate the relationship between olive oil consumption, adherence to MD, and the risk of T2DM among adults aged 19–64 years living in Famagusta, Cyprus. The study hypothesized that higher adherence to the Mediterranean diet (MD), together with increased olive oil consumption, would be associated with a lower risk of T2DM.

Subjects and Methods

Study population and design

This study was conducted with 375 healthy individuals aged 19-64 years residing in Famagusta, Cyprus. The sample size was determined using a random sampling approach, assuming a 95% confidence level and a 5% margin of error. Participants were recruited through household visits conducted within the Famagusta region. Households were approached systematically, and eligible non-diabetic adults were invited to participate, ensuring representation of the target population. Inclusion criteria were as follows: 1) individuals not diagnosed with diabetes by a healthcare provider; 2) individuals not pregnant or breastfeeding; and 3) individuals willing to participate in the study. The study was conducted between November 2022 and July 2023 with participants who met the inclusion criteria (n=375).

Data were collected through face-to-face interviews using a structured questionnaire designed to assess participants' general characteristics, dietary habits, risk of type 2 diabetes mellitus, and adherence to the Mediterranean Diet. Type 2 diabetes risk was evaluated using the Finnish Diabetes Risk Score (FINDRISC), while adherence to the Mediterranean Diet was assessed with the Mediterranean Diet Assessment Scale (MEDAS). The questionnaire was administered alongside anthropometric measurements to obtain comprehensive demographic, clinical, and nutritional information from participants.

Finnish Diabetes Risk Score (FINDRISC)

To assess the risk of type 2 diabetes mellitus (T2DM), the FINDRISC questionnaire was administered. Although several risk-scoring models exist to assess T2DM risk, many require specialized blood test results, limiting their broader application. The FINDRISC scale, developed in 1987 by Tuomiletho and Lindström in Finland, is a simple tool that estimates the 10-year risk of T2DM. The scale consists of 8 questions covering factors such as age, BMI, waist circumference, physical activity, fruit and vegetable consumption, hypertension, hyperglycemia, and family history of diabetes. The total score ranges from 0 to 26, calculated by summing the scores based on individual responses. Risk levels are categorized as follows: a total score below 7 corresponds to a 1% 10-year risk, between 7 and 11 indicates a 4% risk, between 12 and 14 suggests a 16% risk, between 15 and 20 represents a 33% risk, and above 20 points reflects a 50% risk (16).

Mediterranean Diet Assessment Scale (MEDAS)

MEDAS is a 14-item scale developed by Martínez-González MA and colleagues to assess individuals' adherence to the Mediterranean Diet. Participants' adherence is categorized as low (≤5), moderate (6-9), or high (≥10) based on their MEDAS score (17). The validity and reliability of the scale in Turkey were evaluated by Pehlivanoğlu et al. in 2020, and the study concluded that MEDAS is an effective tool for evaluating individuals' dietary habits (18).

Food Frequency Questionnaire (FFQ)

A semi-quantitative food frequency questionnaire (FFQ) was used to assess dietary intake over the preceding three months. The FFQ consisted of 8 sections, including 165 food items, and also assessed olive oil consumption. Participants reported their intake of each food item in terms of meals, days, weeks, or months over the previous 3 months. To facilitate more accurate reporting of food quantities, the Food and Dishes: Portion Sizes and Amount catalogue was provided (19). After determining the daily amounts of foods consumed, daily energy, macronutrient, and micronutrient intakes were calculated using the Nutritional Information Systems Package Software 9 (BEBİS-9).

Anthropometric measurements

Height and weight were measured with participants wearing light clothing and no shoes, following standard protocol. Body mass index (BMI) was then calculated using the formula BMI = weight (kg)/height^2 (m^2) (20). The BMI values were evaluated according to the World Health Organization's (WHO) classification (20). Waist, hip, and neck circumference measurements were taken with participants standing in the Frankfurt Plane. During these measurements, all clothing and accessories that could interfere with accuracy were removed. Waist circumference was measured at the midpoint between the lowest rib and the iliac bone, while hip circumference was taken at the widest point of the hip. Neck circumference was measured just above the Adam's apple (21). Following these measurements, the waist-to-hip and waist-to-height ratios were calculated. All measurements were evaluated based on WHO criteria (22).

Statistical analysis

Statistical analysis of the data obtained from the study was performed using SPSS (Statistical Package for Social Sciences) Version 26.0. The Kolmogorov-Smirnov test, skewness-kurtosis values, and QQ plot were used to assess the normality of the numerical data. Since all data followed a normal distribution, parametric tests were employed for evaluation. The Pearson correlation test was used for assessing relationships between variables, the Chi-square test was used for comparing categorical variables, and the t-test was used for comparing continuous variables between two groups. A p-value of <0.05 was considered statistically significant.

Ethical consideration

This research was deemed appropriate in terms of Scientific Research and Publication Ethics by the X Health Ethics Committee, with a decision number 2022/13. Prior to participation, each participant was provided with an 'Informed Consent Form', which contained general information about the study and confirmed their voluntary agreement to participate. Each participant read and signed the consent form before taking part in the study.

Results

A total of 375 adults participated in the study, including 99 males (26.40%) and 276 females (73.60%), with a mean age of 30.41 ± 11.45 years (Table 1). For male participants, the average body weight was 84.49±17.57 kg, height was 178.86±7.28 cm, body mass index (BMI) was 26.39±5.13 kg/m², waist circumference was 94.37±14.14 cm, hip circumference was 104.90±9.09 cm, waist/hip ratio was 0.90±0.08, waist/height ratio was 0.53±0.08, and neck circumference was 39.58±3.21 cm. For female participants, the average body weight was 64.14±14 kg, height was 164.37±6.58 cm, BMI was 23.76±5.05 kg/m², waist circumference was 79.26±13.70 cm, hip circumference was 101.96±10.51 cm, waist/hip ratio was 0.78±0.09, waist/height ratio was 0.48±0.09, and neck circumference was 32.71±2.93 cm (Table 1).

As shown in Table 2, there is a significant positive correlation between height, BMI (kg/m²), waist circumference, hip circumference, waist/hip ratio, waist/height ratio, and FINDRISC scores in both male and female participants, with the FINDRISC scores increasing as these measurements increase ($p<0.05$).

Table 3 indicates that the majority of participants exhibited moderate adherence to the MD, with only 9.60% of participants demonstrating high adherence. Moreover, it was found that the low level of adherence to the MD was statistically significantly higher in men compared to women ($p<0.05$).

As shown in Figure 1, participants' MEDAS scores were not significantly correlated with their

FINDRISC scores ($p > 0.05$).

Table 4 shows that there are negative correlations between olive oil and butter consumption and the FINDRISC score of the participants. As individuals'

Table 1. Sociodemographic and anthropometric characteristics of study participants

Variable	Male (n=99)	Female (n=276)
	x̄±SD (Min-Max)	
Body weight (kg)	84.49 ± 17.57 (59.60–156.70)	64.14 ± 14.00 (40.10–123.80)
Body height (cm)	178.86 ± 7.28 (155.00–196.00)	164.37 ± 6.58 (149.00–180.00)
BMI (kg/m²)	26.39 ± 5.13 (18.80–47.30)	23.76 ± 5.05 (14.40–39.90)
Waist circumference (cm)	94.37 ± 14.14 (63.00–139.00)	79.26 ± 13.70 (54.00–120.00)
Hip circumference (cm)	104.90 ± 9.09 (70.00–137.00)	101.96 ± 10.51 (81.00–137.00)
Waist–hip ratio	0.90 ± 0.08 (0.70–1.10)	0.78 ± 0.09 (0.60–1.00)
Waist–height ratio	0.53 ± 0.08 (0.36–0.76)	0.48 ± 0.09 (0.34–0.75)
Neck circumference (cm)	39.58 ± 3.21 (32.00–48.00)	32.71 ± 2.93 (28.00–44.00)

consumption of olive oil and butter increases, FINDRISC scores decrease at a statistically significant level. ($p<0.05$). On the other hand, a positive correlation between sunflower oil consumption and T2DM risk was observed. It was found that as participants' sunflower oil consumption increased, their FINDRISC scores also increased at a statistically significant level ($p<0.05$).

Discussion

This study evaluated the associations between anthropometric measurements, adherence to the Mediterranean diet (MD), specific dietary components, and the estimated 10-year risk of type 2 diabetes mellitus (T2DM) assessed using the FINDRISC score. Overall, adiposity related indicators were positively associated with T2DM risk, whereas overall MD adherence was not significantly associated with FINDRISC scores. Certain sources of dietary fat exhibited differential associations with the risk of developing diabetes.

Table 2. The correlation between anthropometric measurements and FINDRISC

FINDRISC			
		Male	**Female**
Body weight (kg)	r	-0.022	-0.027
	p	0.826	0.657
Body height (cm)	r	0.655	0.642
	p	<0.001*	<0.001*
BMI (kg/m²)	r	0.695	0.703
	p	<0.001*	0.000*
Waist Circ. (cm)	r	0.566	0.588
	p	<0.001*	<0.001*
Hip Circ. (cm)	r	0.569	0.508
	p	<0.001*	<0.001*
Waist/hip ratio	r	0.683	0.679
	p	<0.001*	<0.001*
Waist/height ratio	r	0.613	0.620
	p	<0.001*	<0.001*
Neck Circumference	r	-0.022	-0.027
	p	0.826	0.657

**p<0.05, Pearson correlation test.*

Adiposity is a well-established risk factor for Type 2 diabetes mellitus (T2DM), and anthropometric indicators including body mass index (BMI), waist circumference, hip circumference, waist-to-hip ratio, and waist-to-height ratio—are commonly used to evaluate body fat distribution and related metabolic risk (22). Consistent with previous research, the findings of the present study demonstrated positive associations between these anthropometric measures and T2DM risk (22,23). Height has also been examined in relation to diabetes risk; several studies have reported that taller individuals may have a lower likelihood of developing T2DM compared with shorter individuals, although the biological mechanisms underlying this relationship remain unclear (24,25). In contrast to these reports, the present study identified a significant positive association between height and the FINDRISC score ($p < 0.05$). This unexpected result may reflect population-specific characteristics or the influence of residual confounding factors. Overall, these findings highlight the importance of considering multiple anthropometric indicators simultaneously, rather than relying on a single measurement, when evaluating the risk of T2DM.

Statistically significant differences in MEDAS or FINDRISC scores between male and female participants were not observed ($p > 0.05$). Additionally, variations in MEDAS scores showed no significant association with changes in FINDRISC scores, suggesting that adherence to the Mediterranean Diet (MD) did not exert a measurable effect on the estimated 10-year risk of developing type 2 diabetes mellitus

Table 3. Distribution of mediterranean diet adherence levels among study participants

	Male		Female		Total	
MD Adherence Level	**N**	**%**	**n**	**%**	**n**	**%**
Low Adherence	28	28.28	45	16.30	73	19.47
Moderate Adherence	64	64.65	202	73.19	266	70.93
High Adherence	7	7.07	29	10.51	36	9.60

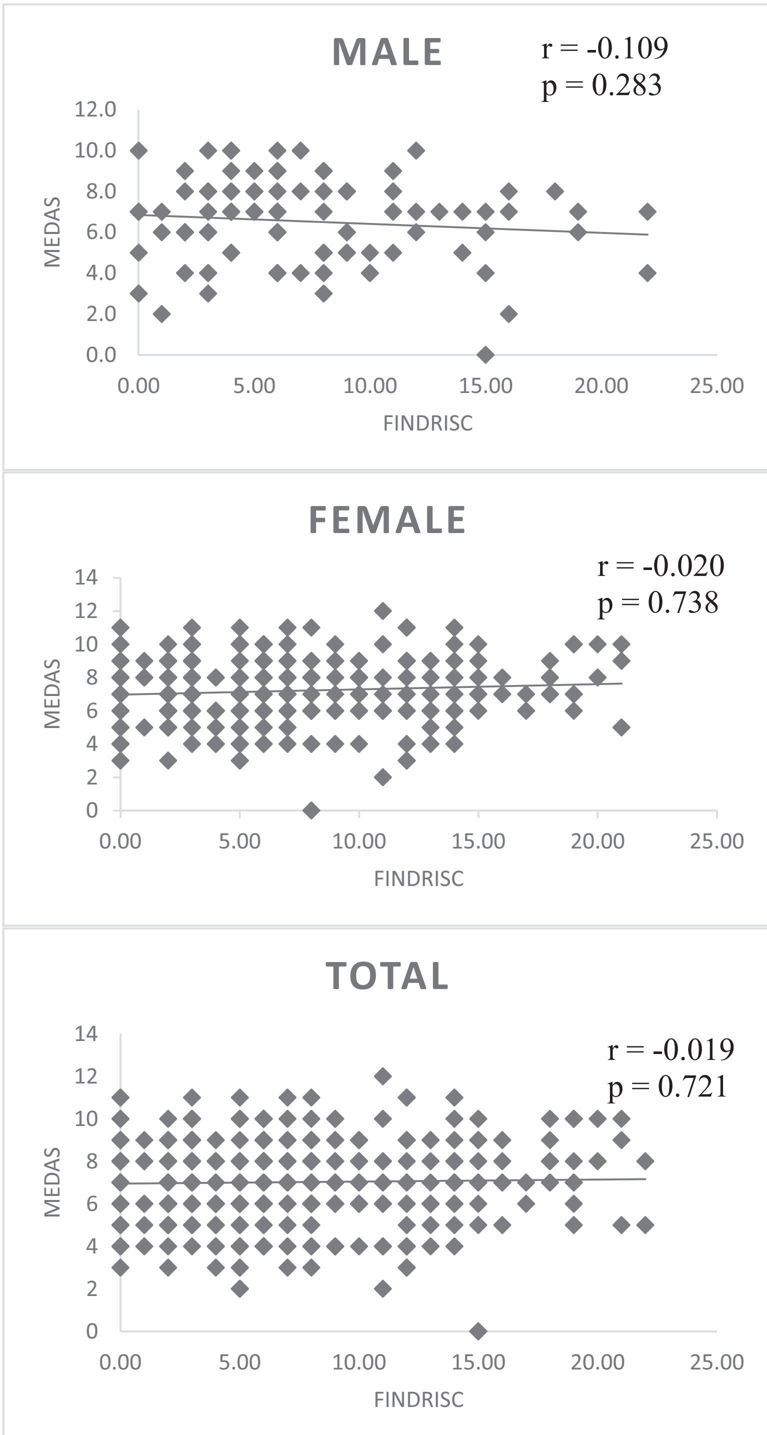

Figure 1. Correlation of MEDAS scores with FINDRISC scores.

Table 4. Correlation between consumption of different dietary fat types and FINDRISC score

Dietary Fat or Food		FINDRISC
Olive oil	r	-0.131
	p	0.011*
Sunflower oil	r	0.105
	p	0.043*
Corn oil	r	0.037
	p	0.471
Coconut oil	r	-0.098
	p	0.057
Tahini	r	0.092
	p	0.076
Margarine	r	-0.021
	p	0.679
Butter	r	-0.121
	p	0.019*

**p<0.05, Pearson correlation test.*

(T2DM) within this study population. Similar findings were reported by Abiemo et al., in which no significant association between Mediterranean Diet (MD) adherence and diabetes risk was identified (26). However, a substantial body of evidence indicates that higher adherence to the MD is associated with a reduced risk of type 2 diabetes mellitus (T2DM) (27,28). A systematic review of randomized controlled and cohort studies conducted by Lukas Schwingshackl et al. (2015) concluded that greater adherence to the Mediterranean Diet (MD) was associated with a 19% reduction in the risk of type 2 diabetes mellitus (T2DM) (9). Similarly, a dose–response meta-analysis published in 2022 reported that each one-point increase in the MD adherence score was associated with a 3% decrease in diabetes risk (27). The protective effect of the MD has been attributed to its high content of antioxidant compounds, vitamins, minerals, dietary fiber, and monounsaturated and polyunsaturated fatty acids (28). The lack of a significant association observed in the present study may be explained by inadequate daily fiber intake and elevated total fat intake, particularly saturated fat, among the participants. The absence of statistically significant differences in MEDAS or FINDRISC scores between male and female participants in Famagusta may be attributable to cultural dietary patterns in the region. In particular, the relatively high consumption of red meat, milk, and dairy products may attenuate the potential beneficial effects associated with adherence to the MD (29). Consistent with findings by Zazpe et al., moderate adherence to the MD in Mediterranean populations may coexist with high consumption of animal based products, which diverges from traditional MD principles (30). Excess intake of red meat and saturated fat may have attenuated the expected protective effect of the MD against T2DM risk.

Despite the lack of association between overall MEDAS and FINDRISC scores, higher adherence to the MD and moderate olive oil consumption were associated with a reduced risk of T2DM, supporting the study hypothesis. The MD emphasizes high consumption of olive oil, vegetables, fruits, legumes, whole grains, fish, and low fat dairy products, moderate red wine intake, and low consumption of red meat (5). Evidence indicates that adherence to the MD exerts protective effects against T2DM. A 22-year longitudinal study among women in the United States demonstrated an inverse association between olive oil intake and T2DM risk, showing that substituting 8 g/day of olive oil for margarine, butter, or mayonnaise was associated with 5%, 8%, and 15% reductions in diabetes risk, respectively (7). Similarly, a recent meta-analysis reported that daily consumption of 25 g of olive oil corresponded to a 22% lower risk of T2DM (31). The anti-diabetic properties of olive oil have been largely attributed to its polyphenolic constituents, particularly oleuropein and hydroxytyrosol, which enhance insulin sensitivity, stimulate glucose-induced insulin secretion from pancreatic β-cells, and mitigate oxidative stress a key contributor to diabetes pathophysiology and its complications. Interestingly, the present study also identified a negative correlation between butter consumption and FINDRISC scores, aligning with the findings of Pimpin et al., who reported that moderate butter intake (14 g/day) was associated with a 4% reduction in T2DM incidence (32). Butter comprises approximately 70% saturated fatty acids, 25% monounsaturated fatty acids, and 5% polyunsaturated fatty acids (33).

Although dietary guidelines generally recommend limiting saturated fat intake, emerging evidence suggests that the metabolic effects of saturated fats may vary according to their food source. Together, these findings underscore the importance of considering both the quality and source of dietary fats when evaluating the protective effects of the MD against T2DM. Dairy products are a rich source of bioactive compounds, including flavonoids, calcium, short and medium chain fatty acids, branched-chain amino acids (BCAAs), trans-palmitoleic acid (trans 16:1n-7), probiotics, and vitamins K1 and K2, which may collectively confer beneficial metabolic effects (34). For instance, yogurt consumption has been associated with a reduced risk of type 2 diabetes mellitus (T2DM), an effect that has been attributed to its probiotic content and unique milk fat composition (32,34). In a 10-year prospective study involving 37,421 participants, Liu et al. reported no significant association between saturated fat intake from milk, dairy products, or butter and the risk of type 2 diabetes mellitus (T2DM), with the exception of cheese, which was linked to a lower risk (35). This protective effect has been attributed to odd-chain saturated fatty acids (OCSFAs), such as pentadecanoic acid (15:0) and heptadecanoic acid (17:0), which are associated with reduced insulin resistance and increased monounsaturated fatty acid accumulation via a PPARα-dependent pathway, thereby mitigating hepatocyte dysfunction and decreasing T2DM risk (36). Conversely, sunflower oil consumption was associated with an elevated risk of type 2 diabetes mellitus (T2DM) in the present study. This relationship may be attributable to its high content of omega-6 fatty acids, particularly linoleic acid. Evidence from a recent study suggests that excessive linoleic acid intake may promote hyperinsulinemia, a key contributor to T2DM pathogenesis (37). Nevertheless, the association between omega-6 fatty acids and diabetes risk is complex and requires further investigation to clarify underlying mechanisms.

Several limitations of the present study should be considered when interpreting the findings. First, the relatively small sample size may have constrained the statistical power to detect modest associations, particularly with respect to the relationship between Mediterranean Diet (MD) adherence and type 2 diabetes mellitus (T2DM) risk. Second, as a single-center study conducted in Northern Cyprus, the generalizability of the results to populations with differing sociodemographic characteristics and dietary patterns may be limited. Third, the disproportionate representation of male participants may further restrict the representativeness of the sample. Additionally, the lack of detailed body composition assessments, including measurements of fat mass, body fat percentage, and lean body mass, limited the comprehensiveness of the anthropometric evaluation. Future multicenter, longitudinal studies with larger and more diverse cohorts, incorporating detailed dietary analyses and advanced body composition measurements, are warranted to more accurately elucidate the associations between dietary patterns, specific fat sources, anthropometric parameters, and T2DM risk.

Conclusion

In conclusion, the findings of the present study indicate that higher olive oil consumption is associated with a lower estimated risk of developing T2DM. Given its rich content of monounsaturated fatty acids and polyphenolic compounds, olive oil may serve as a beneficial primary dietary fat source with potential anti-diabetic properties. Nevertheless, further large-scale studies are warranted to more comprehensively evaluate the dose–response relationship between varying levels of olive oil consumption and T2DM risk.

Conflict of Interest: Each author declares that he or she has no commercial associations (e.g., consultancies, stock ownership, equity interests, patent/licensing, arrangement etc-) that might pose a conflict of interest in connection with the submitted article.

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