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# The relationship of dietary omega-3 fatty acid and omega-6 to omega-3 ratio intake and likelihood of type 2 diabetes in a cross-sectional study

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## Abstract

**Background** There is a belief that consuming a significant amount of omega-3 and omega-6 fatty acids can positively affect chronic diseases. However, the connection between these fatty acids and type 2 diabetes mellitus (T2DM) risk remains unclear. To explore this further, we conducted a study to investigate the relationship between dietary intake of omega-3 and omega-6 fatty acids (FA), as well as omega-6 to omega-3 ratio, and the odds of T2DM.

**Methods** Our research involved a cross-sectional analysis of data from the Ravansar Non-Communicable Disease (RaNCD) cohort. We evaluated their dietary habits using a comprehensive 118-item food frequency questionnaire (FFQ). To determine the aforementioned association, we employed logistic regression analysis to calculate odds ratios (OR) and 95% confidence intervals (CIs).

**Results** The prevalence of T2DM among 8744 qualified participants was 751 (8.6%). After considering all the possible factors that could affect the outcome, high dietary omega-3 intake was associated with a 58% lower likelihood of T2DM (OR: 0.42; 95% CI: 0.32, 0.56; P-trend: <0.001). In contrast, participants at the fourth quartile of the dietary omega 6 to omega 3 FA ratio had a higher odd of T2DM (OR: 1.42; 95%CI: 1.11, 1.84; P-trend: 0.01). Nevertheless, there was no significant connection between the highest and lowest quartile of dietary omega-6 intake (OR: 0.91; 95% CI: 0.71, 1.17; P-trend: 0.80).

**Conclusion** According to the study, consuming omega-3 fatty acids through diet was linked with lower odds of type 2 diabetes. Conversely, an elevated omega-6 to omega-3 ratio was associated with a greater likelihood of T2DM.

**Keywords** Type 2 diabetes, Omega-6, Omega-3, Omega-6/3 ratio, Diabetes mellitus, Diet

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## Introduction

Diabetes mellitus is the most prevalent health issue in recent decades. According to the International Diabetes Federation, the prevalence of diabetes in 2019 was 9.3%, and it is projected to increase to 10.9% by 2045 [1]. Type 2 diabetes mellitus (T2DM) accounts for almost 90% of all diabetes cases, and its prevalence has significantly increased in countries across all income levels [1]. Patients with T2DM usually suffer from major complications including retinopathy, nephropathy, and peripheral neuropathy [2, 3].

Various types of risk factors, including non-modifiable factors such as age, family history, ethnicity, and modifiable factors such as obesity, diet, smoking, alcohol consumption, and physical activity, can elevate the risk of developing T2DM [4, 5]. Previous research suggested that adhering to a healthy dietary pattern, characterized by lower intake of red and processed meats, salt, sugar, saturated and trans fats, and greater consumption of fruits, non-starchy vegetables, legumes, nuts, fish, and vegetable oils, may reduce the risk of T2DM [6].

Essential fatty acids such as omega-3 and omega-6 are polyunsaturated fatty acids (PUFA) that our bodies cannot produce them, so they must be obtained through our diet [7]. They are considered vital components of a healthy eating pattern [8]. Previous meta-analyses have highlighted a positive association between omega-3 fatty acids biomarkers and the risk of total cardiovascular disease (CVD), coronary heart disease, mortality [9] and T2DM [10]. Another meta-analysis suggested an inverse relationship between linoleic acid—the primary omega-6 fatty acids—and the risk of T2DM [11]. These findings may indicate a beneficial association between dietary intake of omega-3 and omega-6 fatty acids and the prevention of T2DM. However, conflicting evidence remains regarding the association between dietary omega-3 and omega-6 fatty acids, and the risk of T2DM. Wu et al., in a systematic review and meta-analysis of cohort studies could not find any significant association between dietary intake of omega-3 polyunsaturated fatty acids and T2DM risk [12]. Another meta-analysis conducted in 2020 found no significant linear association between dietary consumption of omega-6 intake and the risk of T2DM [13]. However, they found a significant inverse association between omega-3 intake and the risk of T2DM in Asian populations, while in US populations, omega-3 intake was associated with a significant increase in T2DM incidence [13].

In addition to the individual associations of omega-3 and omega-6 fatty acids with T2DM, the dietary omega-6 to omega-3 fatty acids ratio is also remarkably important. Research indicates that a higher omega-6 to omega-3 ratio is associated with increased inflammation and heightened risk of autoimmune diseases, cancer, CVD, and diabetes [14, 15]. However, in a 2019 meta-analysis of randomized clinical trials (RCTs), Brown et al. found that higher ratio of omega-3/omega-6 intake had no effect on the prevention and treatment of type 2 diabetes mellitus [16]. Above mentioned systematic-review and meta-analysis of two cohort studies conducted in 2020, could not also find any significant association between omega-6/omega-3 ratio and risk of T2DM [13]. Overall, further observational studies are needed for several reasons: first, there is conflicting evidence on the association between omega-3, omega-6, and particularly the omega-6/omega-3 ratio, with T2DM risk; second, no observational studies have yet examined this relationship within the Iranian population; and finally, few studies have investigated the association between dietary omega-6 to omega-3 ratio and T2DM [17–19]. Therefore, this cross-sectional study, based on cohort data, aims to assess the association between dietary intake of omega-3 and ometga-6 fatty acids, as well as the omega-6/omega-3 ratio, with the odds of T2DM.

## Methods

### RaNCD study

Ravansar Non-Communicable Disease (RaNCD) study is a population-based prospective cohort study that was performed with the aim of evaluating the non-communicable diseases in Iranian Kurdish ethnicity in Ravansar city, Kermanshah province. More details about the study have been published previously [20–22]. The RaNCD cohort is part of the Prospective Epidemiological Research Studies in Iran (PERSIAN) cohort study. Data collection was carried out on 10,025 adults aged 35–65 years, from October 2014 up to August 2022 [20]. We excluded 1281 participants including, 774 participants who had a calorie intake of more than 4200 kcal or less than 800 kcal per day, 131 pregnant women, 78 subjects with cancer, 76 patients diagnosed with renal failure, as well as 222 cases with missing information. Overall, we included 8744 eligible participants in the final analyses (Fig. 1).

### Data collection

#### *Dietary intake measurement*

We gathered dietary information of the study participants using a reliable and accurate 118-item food frequency questionnaire (FFQ) [20]. This questionnaire included the standard portion sizes of typical local foods consumed by the Iranian Kurdish population [20]. FFQ was completed by trained researchers, and then the food item frequency was converted to grams per day. Daily energy, macro, and micronutrients, as well as PUFA intakes of each subject were assessed by Nutritionist IV software which is a revised food composition dataset for

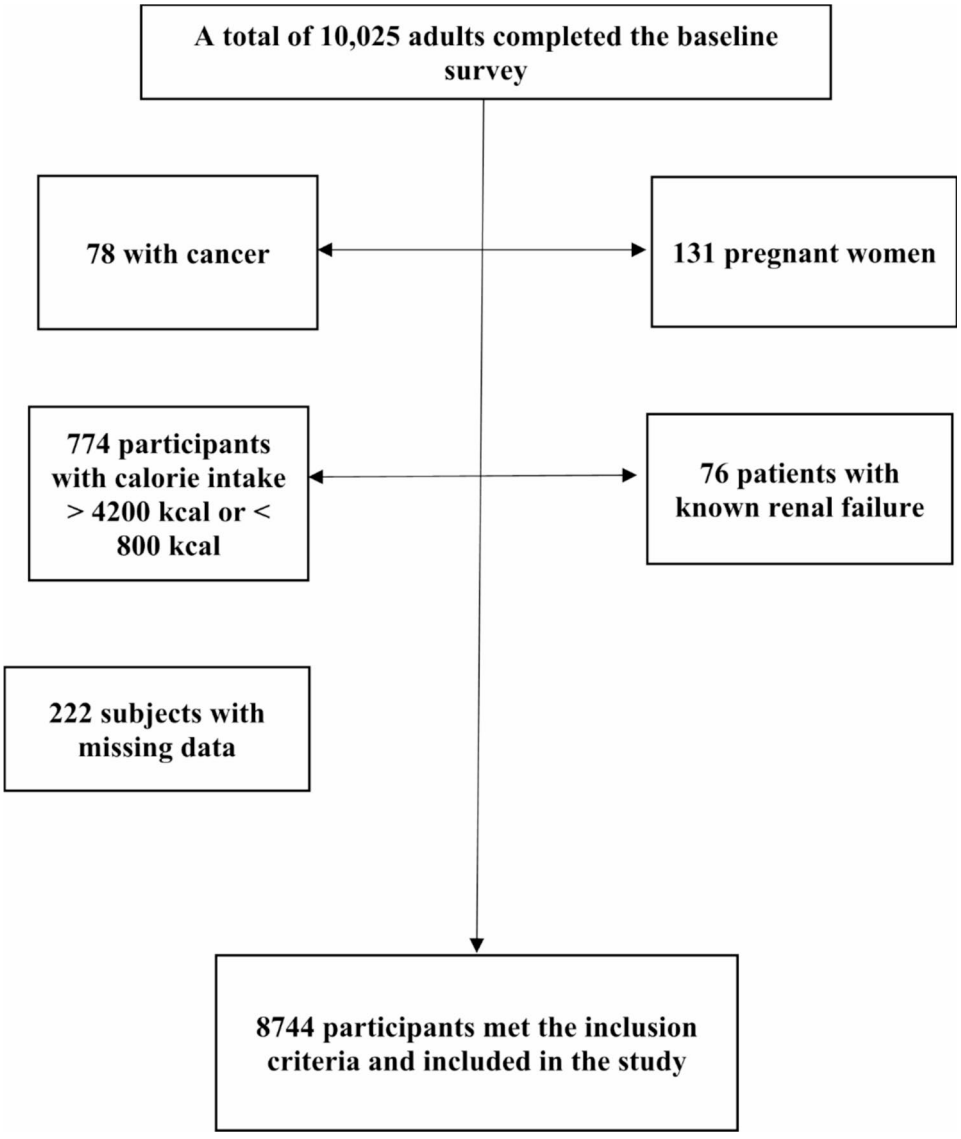


**Fig. 1** Flowchart of the present study

Iranian foods in agreement with the US Department of Agriculture [23].

#### *Identification of T2DM*

In the present study, we defined type 2 diabetes mellitus as fasting blood sugar≥126 mg/dL and/or a history of diabetes medication including Metformin, acarbose, glibenclamide, sitagliptin, gliclazide, repaglinide, reserpine, insulin regular, novorapid, lantus, novomix, and /or having diabetes confirmed by a health practitioner [24, 25].

#### *Assessment of other factors*

In the present study to collect information we used clinical examinations and face-to-face interviews. An application was used to fill out all the questionnaires and a team of specialists ensured their accuracy. Moreover, we utilized an electronic questionnaire system available online to register the sociodemographic data including age, gender, physical activity, living habitat, marital status, education, economic status, as well as personal behaviors such as smoking history, in addition to history of chronic diseases. We assessed body weight as well as body mass index (BMI) with a Bio-Impedance Analyzer BIA (Inbody 770, Inbody Co, Seoul, Korea) [20]. Participants were instructed to remove their shoes, heavy clothing, and accessories to obtain precise anthropometric measurements. Height was measured using BSM 370 with a precision of 0.1 cm (Biospace Co, Seoul, Korea). We used flexible and non-stretch tape to measure waist circumference (WC) and hip circumference (HC) using the standard method. Then, we calculated waist-to-hip ratio by dividing WC by HC in centimeters. The physical

activity of subjects was evaluated using a 22-item PERSIAN Cohort standard physical activity questionnaire. According to physical activity intensity, we classified participants as light, moderate, and high physical activity.

### Statistical analysis

We controlled dietary PUFA including omega-3 and omega-6 as well as omega-6 to omega-3 ratio for total energy intake using a method introduced by Willett [26]. We classified all subjects based on the quartiles of energy-adjusted dietary omega-3, omega-6, and omega-6/omega-3 ratio, then the first quartile was regarded as a reference. The study participants' traits across the quartiles of energy-adjusted dietary omega-6, omega-3, and omega-6/omega-3 ratio were reported as mean ± standard deviation (SD) from ANOVA analysis for continuous variables, and number (%) using Chi-square analysis for qualitative variables. Logistic regression analyses were utilized to estimate the odds ratios (OR) and 95% confidence intervals (CIs) to assess the possible association between dietary intake of omega-6, omega-3, and the ratio of omega-6 to omega-3 with the probability of developing T2DM. We also considered some variables as potential confounders in the analyses. Then, we defined three logistic regression models as follows: Model 1 (crude model), model 2 (adjusted for gender and age), and model 3 (additionally controlled for age, gender, residence type, marital status, BMI, smoke, carbohydrate percentage, protein percentage, energy intake, fiber, history of CVD, physical activity, education, and socioeconomic status). P for trend was calculated by treating quartile categories as continuous in logistic regression analysis. The statistical analyses were performed using SPSS software (version 26). A p-value of $<0.05$ was considered statistically significant.

A dose-response analysis was performed to examine the association between of dietary omega-6, omega-3, and the omega-6 to 3 ratios fatty acid intake and the odds of T2DM. Participants were categorized into quartiles based on their omega-3 intake. Adjusted (model 3) odds ratios (ORs) and 95% confidence intervals (CIs) were calculated for each quartile, with the lowest quartile serving as the reference group. To visualize the dose-response relationship, we plotted the ORs against the mean omega-3 intake for each quartile.

## Results

Out of 8744 eligible participants, a total of 1480 (16.9) cases of CVD and 751 (8.6) cases of T2DM were identified. Table 1 presents data regarding the characteristics of the participants based on their intake of dietary omega-6, omega-3, and the omega-6 to 3 ratios. Individuals at top intake of omega 3 were typically younger, male, smokers, had a higher socioeconomic status, were married, living in urban areas, had a low level of education, and were less likely to have a history of CVD, and physical activity. Instead, those with a higher intake of omega 6 were generally younger, heavier, female, living in urban areas, had a higher socioeconomic status, history of CVD and diabetes, and were less likely to physically active, smoke, and educated. The individuals who were in the fourth quartile of the omega 6:3 ratio were more likely to be female, living in urban areas, and had a higher socioeconomic status. They were also younger and heavier compared to others. Their cardiovascular disease history was

**Table 1** The study participants' general characteristics based on their quartile (Q) of intake for omega-3, omega-6, and the ratio of omega-6 to omega-3 fatty acids

| ** | Omega-3 | | | Omega-6 | | | Omega-6: Omega-3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q4 | *P** | Q1 | Q4 | *P** | Q1 | Q4 | *P** |
| Age (Y) | 47.8 ± 8.1 | 46.4 ± 8.1 | < 0.001 | 48.1 ± 8.3 | 46.2 ± 7.9 | < 0.001 | 47.6 ± 8.3 | 46.8 ± 7.9 | < 0.001 |
| BMI | 27.5 ± 4.6 | 27.4 ± 4.4 | 0.817 | 26.8 ± 4.7 | 27.9 ± 4.5 | < 0.001 | 27.1 ± 4.6 | 28.1 ± 4.6 | < 0.001 |
| WHR | 0.94 ± 0.1 | 0.95 ± 0.1 | 0.036 | 0.93 ± 0.1 | 0.94 ± 0.1 | < 0.001 | 0.93 ± 0.1 | 0.94 ± 0.1 | 0.178 |
| Female | 1318 (60.3) | 825 (37.7) | < 0.001 | 997 (45.6) | 1235 (56.5) | < 0.001 | 850 (38.9) | 1351 (61.8) | < 0.001 |
| Urban-resident | 1157 (52.9) | 1524 (69.7) | < 0.001 | 853 (39) | 1704 (78) | < 0.001 | 1089 (49.8) | 1586 (72.6) | < 0.001 |
| Married | 1955 (89.4) | 2027 (92.7) | < 0.001 | 1979 (90.5) | 1971 (90.2) | 0.012 | 2003 (91.6) | 1956 (89.5) | 0.008 |
| Current smoker | 237 (10.8) | 306 (14) | < 0.001 | 318 (14.5) | 203 (9.3) | < 0.001 | 324 (14.8) | 165 (7.5) | < 0.001 |
| High SES | 273 (12.5) | 713 (32.6) | < 0.001 | 232 (10.6) | 640 (29.3) | < 0.001 | 396 (18.1) | 510 (23.3) | < 0.001 |
| High physical activity | 544 (24.9) | 490 (22.4) | < 0.001 | 682 (31.2) | 341 (15.6) | < 0.001 | 631 (28.9) | 354 (16.2) | < 0.001 |
| University graduated | 1185 (54.2) | 772 (35.3) | < 0.001 | 1163 (53.2) | 865 (39.6) | < 0.001 | 1003 (45.9) | 987 (45.2) | < 0.001 |
| Prevalence of diabetes | 177 (8.1) | 207 (9.5) | 0.251 | 159 (7.3) | 206 (9.4) | 0.013 | 171 (7.8) | 191 (8.7) | 0.513 |
| Family history of diabetes | 566 (25.9) | 560 (25.6) | 0.701 | 485 (22.2) | 630 (28.8) | < 0.001 | 504 (23.1) | 609 (27.9) | 0.001 |
| Prevalence of CVD | 341 (15.6) | 326 (14.9) | < 0.001 | 312 (14.3) | 373 (17.1) | 0.001 | 322 (14.7) | 384 (17.6) | 0.018 |

BMI: Body mass index; WHR: Waist-to-hip ratio; DBP: Diastolic blood pressure; SBP: Systolic blood pressure; SES: Socioeconomic status; CVD: Cardiovascular disease

* P-value attained by ANOVA for continuous variables and chi-square test for categorical variables

** Continuous variables are reported as mean ± sd and categorical variables are reported as number (precent)

**Table 2** The nutrient intake of the individuals under study based on the quartile (Q) classification of omega-3, omega-6, and the ratio of omega-6 to omega-3 fatty acids

| | Omega-3 | | | Omega-6 | | | Omega-6: Omega-3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q4 | *P** | Q1 | Q4 | *P* | Q1 | Q4 | *P** |
| Energy (Kcal/d) | 2830.4 ± 647.3 | 2654.4 ± 724.6 | < 0.001 | 2775.9 ± 657.9 | 2594 ± 751.8 | < 0.001 | 2726.9 ± 695.6 | 2647.3 ± 726.8 | < 0.001 |
| Carbohydrate (%Kcl) | 63.2 ± 6.1 | 58.7 ± 5.9 | < 0.001 | 62.5 ± 5.9 | 60.3 ± 5.8 | < 0.001 | 60.6 ± 6.2 | 61.7 ± 5.9 | < 0.001 |
| Protein (%Kcl) | 12.4 ± 1.6 | 15.6 ± 2.1 | < 0.001 | 13.7 ± 2.1 | 14 ± 0.04 | < 0.001 | 14.9 ± 2.2 | 12.9 ± 1.8 | < 0.001 |
| Fat (%Kcl) | 26.1 ± 6.1 | 27.7 ± 5.5 | < 0.001 | 25.2 ± 5.3 | 28.3 ± 5.4 | < 0.001 | 26.1 ± 5.5 | 27.6 ± 5.9 | < 0.001 |
| Fiber (g/d) | 24.7 ± 8.6 | 24.3 ± 8.6 | < 0.001 | 22.8 ± 7.9 | 24.6 ± 9.1 | < 0.001 | 23.2 ± 8.2 | 24.8 ± 8.9 | < 0.001 |
| Sodium (g/d) | 5356.3 ± 1863.9 | 4554.8 ± 1712.7 | < 0.001 | 5245.3 ± 1806.8 | 4592.2 ± 1767.4 | < 0.001 | 4970.8 ± 1810.6 | 4843.3 ± 1832.3 | < 0.001 |
| Calcium (mg/d) | 1433.3 ± 455 | 1231.3 ± 430 | < 0.001 | 1428.6 ± 453.9 | 1179.4 ± 423.4 | < 0.001 | 1353.2 ± 464.1 | 1244.3 ± 446 | < 0.001 |
| Magnesium (mg/d) | 328.4 ± 94.4 | 342.1 ± 101.8 | < 0.001 | 320.9 ± 91.1 | 330.5 ± 107.8 | < 0.001 | 330.3 ± 95.2 | 327.3 ± 102.5 | < 0.001 |
| Potassium (mg/d) | 3140.4 ± 1094 | 3478.3 ± 1137.4 | < 0.001 | 2054.2 ± 1067.8 | 3336.9 ± 1165.9 | < 0.001 | 3247.2 ± 1105.9 | 3250.7 ± 1119.8 | < 0.001 |

* P-value attained by ANOVA

**Table 3** The odds ratio and 95% confidence intervals for type 2 diabetes based on quartile categories of intake for omega-3, omega-6, and the ratio of omega-6 to omega-3 fatty acids

| | **Omega-3 intake** | | | | |
|---|---|---|---|---|---|
| | **Q1** | **Q2** | **Q3** | **Q4** | ***P* trend** |
| Mean Omega-3 intake (g/d) | 0.05 ± 0.01 | 0.07 ± 0.01 | 0.08 ± 0.01 | 0.12 ± 0.03 | |
| Model 1 | 1 | 1.09 (0.88–1.36) | 0.98 (0.78–1.22) | 1.18 (0.96–1.46) | 0.226 |
| Model 2 | 1 | 1.08 (0.87–1.34) | 0.99 (0.79–1.24) | 1.34 (1.08–1.66) | 0.023 |
| Model 3 | 1 | 0.78 (0.62–0.99) | 0.52 (0.40–0.67) | 0.42 (0.32–0.56) | < 0.001 |
| | **Omega-6 intake** | | | | |
| | Q1 | Q2 | Q3 | Q4 | P trend |
| Mean Omega-6 intake (g/d) | 3.26 ± 0.75 | 4.87 ± 0.38 | 6.65 ± 0.65 | 10.41 ± 2.42 | |
| Model 1 | 1 | 1.11 (0.88–1.38) | 1.36 (1.09–1.68) | 1.32 (1.07–1.64) | 0.003 |
| Model 2 | 1 | 1.09 (0.87–1.37) | 1.42 (1.14–1.76) | 1.50 (1.20–1.87) | < 0.001 |
| Model 3 | 1 | 0.84 (0.65–1.07) | 0.93 (0.73–1.18) | 0.91 (0.71–1.17) | 0.803 |
| | **Omega-6: Omega-3 intake** | | | | |
| | Q1 | Q2 | Q3 | Q4 | P trend |
| Mean Omega-6 to 3 intakes (g/d) | 41.33 ± 10.60 | 64.15 ± 5.26 | 87.07 ± 8.56 | 150.76 ± 54.16 | |
| Model 1 | 1 | 1.13 (0.91–1.41) | 1.17 (0.94–1.44) | 1.13 (0.91–1.39) | 0.267 |
| Model 2 | 1 | 1.08 (0.87–1.35) | 1.18 (0.95–1.47) | 1.17 (0.94–1.46) | 0.111 |
| Model 3 | 1 | 1.36 (1.07–1.72) | 1.38 (1.08–1.76) | 1.42 (1.11–1.84) | 0.01 |

Model 1: crude model

Model 2: Age and gender

Model 3: Age, gender, residence type, marital status, BMI, smoke, carbohydrate percentage, protein percentage, energy intake, fiber, history of CVD, physical activity, education, socioeconomic status

higher, although they were less likely to smoke or engage in physical activity.

Table 2 displays the dietary nutrient intake of the participants in the study, categorized by quartiles of dietary omega 3, omega 6, and the ratio of omega 6 to omega 3. Those in the highest quartile of dietary omega-3 intake had greater consumption of protein, fat, and magnesium, but lower consumption of energy, sodium, carbohydrates, and calcium. Participants in the top quartile of dietary omega-6 intake consumed more fiber, fat, potassium, and magnesium, but less carbohydrates, sodium, energy, and calcium. Individuals in the highest quartile for the dietary omega 6:3 ratio had a reduced consumption of protein and calcium but a greater intake of carbohydrates, fat, and fiber.

Table 3 provides the OR and 95% CI for T2DM based on quartile categories of dietary omega-3, omega-6, and omega-6:3 fatty acids. In the initial model (model 1), there was no significant association between the dietary omega-3 intake and omega 6:3 ratio and the odds of T2DM. However, a higher dietary omega 6 was significantly linked to developed odds of T2DM (OR: 1.24; 95% CI: 1.05, 1.45; P-trend: 0.012). After accounting for age and gender in model 2, a noteworthy association was observed between T2DM and dietary omega-3 (OR: 1.34; 95% CI: 1.08, 1.66; P-trend: 0.023) and omega-6 (OR: 1.50; 95% CI: 1.20, 1.87; P-trend < 0.001). However, in the third model, accounting for all confounders, the top quartile of dietary omega-3 intake exhibited an inverse association with T2DM versus the first quartile (OR:

0.42; 95% CI: 0.32, 0.56; P-trend: <0.001). Moreover, participant at the fourth quartile of the omega 6 to omega 3 ratio had higher odds of T2DM (OR: 1.42; 95%CI: 1.11, 1.84; P-trend: 0.01).

Figure 2 shows the dose response analysis of omega-3, omega-6 and omega 6 to 3 intake in relation to T2DM. Regarding dietary omega-3 intake, the analysis indicated a clear trend where higher quartiles of omega-3 intake were associated with lower odds of type 2 diabetes, supporting the hypothesis of a protective effect (P for trend: <0.001). The dose response analysis for intake of omega-6 to omega-3 ratios showed a clear trend where higher ratio was associated with increased odds of type 2 diabetes (P for trend: <0.01). However, the results indicate no linear relationship between dietary omega-6 intake and T2DM (P for trend: 0.803).

## Discussion

The current cross-sectional study revealed that a greater amount of omega-3 in one's diet was associated with lower chances of T2DM and higher ratio of omega-6 to 3 was related with higher chance of T2DM. Nevertheless, no significant link was seen between dietary consumption of omega-6 and T2DM.

It is believed that chronic diseases can be improved by consuming a significant amount of polyunsaturated fatty acids, specifically omega-3 and omega-6 [16]. However, the link between omega-3 fatty acids as well as omega-6 and type 2 diabetes risk are not yet conclusive. Similar to our findings, the Singapore Chinese Cohort Study conducted in 2011 yielded similar findings, indicating that higher intake of omega-3 FAs was linked to a lower incidence of diabetes [18]. Also, the incidence of type 2 diabetes was not found to be associated with dietary omega-6 intake [18]. A pooled analysis on 20 prospective cohort studies in 2021 indicated that higher levels of omega-3 FA biomarkers in circulation were connected with lower risk of T2D [27]. On the contrary, a dose response meta-analysis of cohort studies conducted in 2022 found that the consumption of omega-3 FA nonlinearly increased the T2DM risk [28]. A systematic review and meta-analysis of randomized controlled trials in 2019 found no evidence to support the claim that increasing omega-3, omega-6, or PUFA had any effect on preventing or treating type 2 diabetes mellitus [16]. Interestingly, in 2017, a meta-analysis of various cohort studies indicated that there was no noteworthy correlation between the consumption of omega-3 and the possibility of developing type 2 diabetes [29]. However, after conducting a subgroup analysis, it was discovered that there exists a noteworthy inverse correlation between the consumption of omega-3 and the risk of type 2 diabetes in individuals of Asian ethnicity [29]. This implies that a range of factors, such as age, dosage, and ethnicity, could have an impact on the effect of omega-3 in the management of type 2 diabetes.

Studies have demonstrated that omega-3 PUFA can enhance multiple metabolic abnormalities that lead to

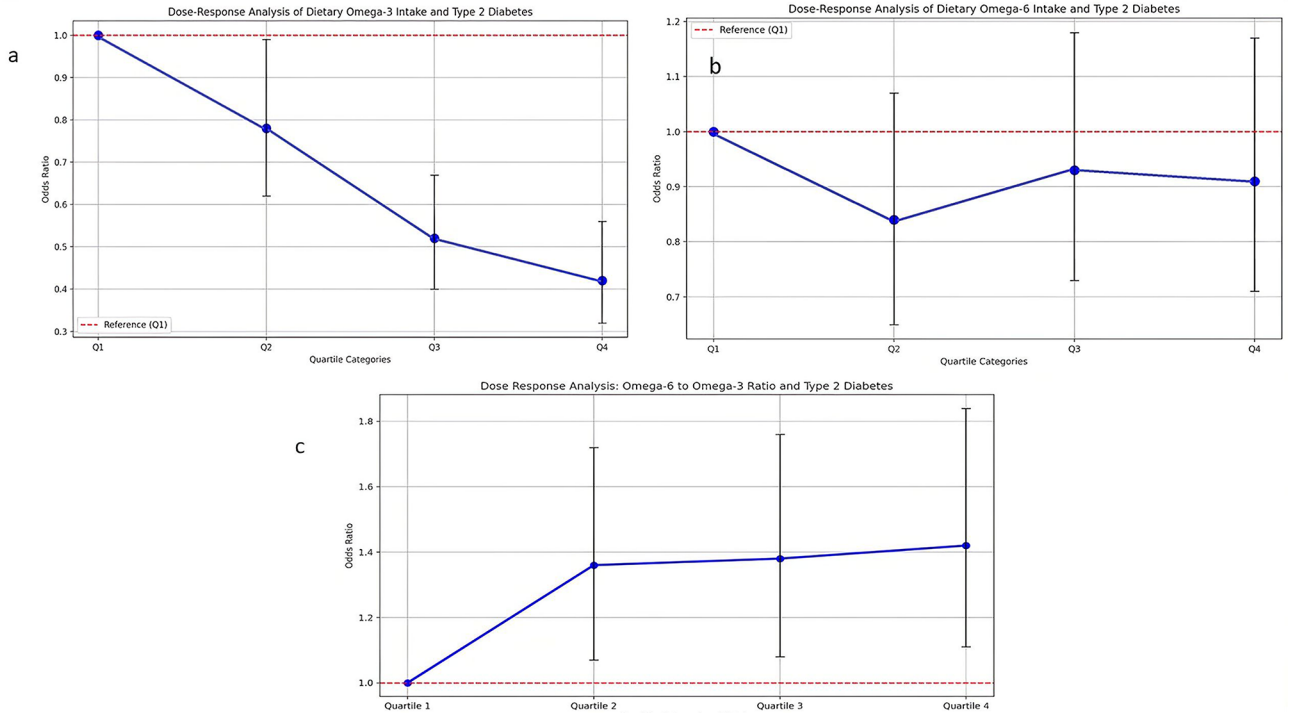


**Fig. 2** Dose response analysis of omega-3, omega-6 and omega 6 to 3 intake in relation to type 2 diabetes mellitus

the onset of DM. These advantages consist of heightened manufacturing and excretion of adiponectin, which can assist in improving insulin sensitivity [30]. The anti-inflammatory effects of omega-3 can help in preventing insulin resistance either by direct or indirect means such as conversion to specialized pro-resolution mediators like resolvins and protectins [31]. Moreover, oxidative stress plays a crucial role in the development of complications related to type 2 diabetes [32]. Omega-3 fatty acids possess antioxidant properties that can mitigate oxidative stress and safeguard against such complications [32]. Sterol regulatory element binding protein-1c can be modified by omega-3 fatty acids to enhance fatty acid oxidation and decrease de novo lipogenesis [32]. This can lead to a reduction in hepatic fat accumulation and help to maintain hepatic insulin sensitivity. Moreover, omega-3 fatty acids may positively influence gut microbiota composition, promoting a healthy microbiome that is associated with improved metabolic health [33]. A balanced gut microbiome can enhance gut barrier function and reduce systemic inflammation, further contributing to the prevention of T2DM [33]. In summary, omega-3 fatty acids may protect against T2DM by improving insulin sensitivity, reducing inflammation and oxidative stress, modulating lipid metabolism, and positively influencing gut microbiota.

The top quartile of the dietary ratio likely represents a higher intake of omega-6 fatty acids relative to omega-3 fatty acids, which could contribute to the T2DM. This aligns with previous research suggesting that maintaining a balanced ratio of these fatty acids is important for metabolic health [34]. Omega-6 fatty acids tend to be pro-inflammatory, while omega-3 fatty acids have anti-inflammatory properties [34]. A high omega-6 to omega-3 ratio can lead to chronic inflammation, which is a known risk factor for insulin resistance and T2DM [34]. These results underscore the importance of dietary balance between omega-6 and omega-3 fatty acids in the prevention of T2DM. Future research should focus on identifying optimal dietary patterns and interventions to achieve this balance and reduce the risk of T2DM.

The study's robust sample size and examination of the connection between omega-3, omega-6, and T2DM in a Middle Eastern nation are noteworthy strengths. However, some limitations could not be avoided. Firstly, the study was cross-sectional, so it could not establish a cause-and-effect relationship between exposure and outcome. Although the diet was measured with some inaccuracies, this would likely result in underestimating risk. Furthermore, despite accounting for all covariates, residual confounding factors may still exist. Lastly, the study only focused on Iranian Kurds, so it is important to exercise caution when generalizing the findings to other populations with distinct demographic characteristics.

Based on our research, it seems that omega-3 fatty acids may have a protective effect against T2DM. However, more studies are necessary to confirm a cause-and-effect relationship. It's crucial to conduct randomized controlled trials to assess the effectiveness and safety of omega-3 supplementation in lowering the risk of T2DM. Furthermore, it's important to investigate the ideal dosage, duration of intake, and potential interactions with other dietary and lifestyle factors. In the meantime, adding omega-3-rich foods to a healthy diet can be part of an overall strategy to prevent T2DM. Fatty fish such as salmon, mackerel, and sardines, as well as flaxseeds, chia seeds, and walnuts are all excellent sources of omega-3 fatty acids.

## Conclusion

According to evidence from a cross-sectional study, a higher intake of dietary omega-3 FA was associated with a lower likelihood of T2DM. In contrast, a higher ratio of omega-6 to omega-3 fatty acids was linked to an increased odd of T2DM. However, the intake of omega-6 fatty acids did not show significant associations with T2DM.

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#### Author contributions

The study's design was contributed to by ESH, FN, YP, AS, and MHSH. AB and FA were responsible for data analysis and manuscript writing. The manuscript was extensively reviewed and edited by AB.

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#### Data availability

The manuscript includes all the data that was created and analyzed during the study.

## Declarations

#### Ethics approval and consent to participate

The study was approved by the Ethics Committee of Kermanshah University of Medical Sciences (KUMS.REC. 1400.670). The study was conducted following the appropriate guidelines and regulations. The International Conference on Harmonisation and the ethical principles of the Declaration of Helsinki were taken into account during the study. Written informed consent was obtained from all participants prior to their involvement in the study.

#### Consent for publication

Not applicable.

#### Competing interests

The authors declare no competing interests.

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