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Association between dietary fatty acid patterns and obesity indices in Jordanian adults: A cross-sectional study

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ABSTRACT

Background: The ratios of fatty acids in different diets and their connection to chronic diseases including obesity and CVD have been researched. The current study set out to detect the dietary fatty acid patterns among Jordanian adults and their relationships with obesity indices.

Methods: The data of 1096 adults were extracted from a household food consumption patterns survey study. Food intake was analyzed, and fatty acid patterns were determined. After anthropometric measurements, obesity indices were calculated.

Results: Two fatty acid patterns were determined (High fatty acids from Protein and Olive Oil sources pattern, and the low Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) pattern), explaining an overall variance of 41.78% and 24.31%, respectively. A significant difference in obesity scores through fatty acids pattern quartiles was only seen among female participants. Q4 of the "High fatty acids from Protein and Olive Oil sources" pattern had a significantly higher means of body mass index (25.12 ± 0.46; $p = 0.015$), waist-to-height-ratio (0.51 ± 0.01; $p = 0.002$), weight-adjusted waist index (10.13 ± 0.09; $p = 0.021$) and body roundness index (3.61 ± 0.15; $p = 0.007$) compared to Q1, while Q4 of "Low EPA and DHA" pattern had significantly higher means of waist circumference (WC) (86.28 ± 1.34) and a body shape index (ABSI) (10.12 ± 0.30) in comparison to Q1 (WC = 81.55 ± 1.08 and ABSI = 9.07 ± 0.22; $p = 0.025$, 0.013; respectively). In females, there was a significant association between the "High fatty acids from Protein and Olive Oil sources" pattern and all the obesity indices.

Conclusion: Our results suggest that an increase in the high fatty acids from Protein and Olive Oil sources pattern is associated with a reduction in obesity indices, which is opposite to the low EPA and DHA pattern. This was a sex-specific association.

1. Introduction

Obesity is known as a risk factor for various chronic diseases, including hypertension, type 2 diabetes (T2DM), and cardiovascular disease (CVD) [1]; these diseases are also known as diet-related chronic diseases, and they are very prevalent among adults as

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documented by the Dietary Guidelines for Americans (DGA) [2,3]. Moreover, the most recent Dietary Guidelines focused on healthy individuals, as well as those overweight or obese, to reduce the prevalence of chronic diseases or more to prevent their incidence via controlling weight gain [2]. Usually, general obesity is diagnosed using the body mass index (BMI), while abdominal or central obesity is diagnosed either by measuring waist circumference (WC) or by calculating the waist-to-height ratio (WHtR) [4]. However, less commonly, novel obesity indices have also been used to identify obese or overweight individuals, such as the weight-adjusted-waist index (WWI), conicity Index (CI), body roundness index (BRI), and a body shape index (ABSI) [5–8].

Diet is the critical key to weight as well as chronic diseases; this fact is comprehensively studied for decades and has been scientifically evidenced [9,10]. Several studies have underlined the problems of increased adiposity and its relationship with the consumption of different food items, food groups, and many nutrients [9–11]. Remarkably, these foods and nutrients were eaten together as a combination of dietary intake patterns, so we can't neglect the synergistic effect of diet. Dietary intake patterns have been defined as the amounts, proportions, variety, or combination of various foods, beverages, and nutrients in diets, as well as the regularity with which they are routinely consumed [11]. Recent studies are focused on dietary patterns and their contribution to obesity and non-communicable diseases (NCDs) [12–16]. Furthermore, the 2020–2025 DGA emphasizes the importance of adaptation to a healthy dietary pattern as a whole rather than focusing on or changing an individual nutrient or food item, or food group in isolation [11,17]. In Jordan, it has been approved that most of the university students did not meet the intake of daily recommendations for fruits and vegetables (76% and 82%; respectively). Also, males were significantly consuming fast food more frequently ($p = 0.019$) than females [18]. Tayyem and colleagues [19] found that metabolic syndrome participants reported a significantly higher intake of the amount of proteins, carbohydrates, fibers, sugars, saturated fat, monounsaturated, polyunsaturated, *trans*-fat, omega-3, and as compared to the metabolic syndrome-free. Moreover, they itemized three major dietary patterns among Jordanian adults; "fast food dietary pattern", "Mediterranean dietary pattern" and "high-protein dietary pattern", a direct significant trend between metabolic syndrome and fast food pattern was detected [19]. Furthermore, eating habits of Jordnians had been affected by COVID-19 pandemic; their lifestyle has been affected, food consumption was increased and shifted to eating sugar and fats, and physical activity was decreased, accompanied by an increase in screen time [20].

Fat is an energy-yielding macronutrient that contributes to a rising prevalence of obesity when consumed in excess amounts [10]. Thus, dietary guidelines for more than four decades emphasized reducing daily fat consumption [9,10]. Conversely, recent studies discovered that only certain types of fat have been linked to obesity as well as chronic diseases such as CVD, stroke, T2DM, and certain types of cancers [21,22]. For instance, high consumption of saturated fatty acids (SFA) has been associated with obesity, CVD, and T2DM, while increased intake of monounsaturated fatty acids (MUFA) was connected to reducing CVD risk [17,23]. Furthermore, Brayner and colleagues concluded that a dietary pattern with higher SFA and lower PUFA foods was associated with obesity and abdominal obesity but not with T2DM [16]. More specifically, fatty acid proportions within individual diets were also considered, and their relationship to chronic diseases including CVD and obesity has been widely studied [23,24].

As per our knowledge, a conflicting findings regarding the linkage of certain types of fats to obesity as well as chronic diseases, also no research has looked into the dietary fatty acid patterns of Jordanian adults, therefore the current study was conducted to detect these patterns and examine the relationships between them and obesity indices in Jordanian adults.

2. Methods

2.1. Study design and ethical approval

This analysis used data from a survey of household consumption patterns in the Jordanian population between 2021 and 2022, the manuscript data have been extracted from the household study which was described in details By Al-Shami and colleagues [25]. This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Institutional Board Review (IRB) committee reviewed at Hashemite University (No.7/13/2020/2021). Written informed consent was obtained from all subjects.

The participants were a representative sample of 701 households. 632 families consented to participate, with a 90.2% response rate, and they were chosen at random from Jordan's three main regions (Central, Northern, and Southern). 2721 household members in all were contacted, and 2145 agreed to take part (8–64 years). A total of 1096 apparently healthy (self-reported no disease) Jordanian adults aged 20 to 64 were included in this study. Pregnant or lactating women, participants with health conditions, food allergies or intolerance, disabilities, or who reported medically diagnosed diseases were excluded. Also, the outlier values were calculated and excluded, a detailed protocol has been described by Al-Shami and colleagues [25].

2.2. Data collection

A face-to-face interview was conducted with the participant to obtain sociodemographic data, general health status, presence of chronic diseases, and use of dietary supplements. In addition, anthropometric measurements and the first 24-h food recall (24-h DR) were collected, while a telephone interview was conducted for the second 24-h DR. A well-trained nutritionist obtained all of this data after participants signed an informed consent form. The detailed protocol has been published by Al-Shami and colleagues [25].

2.3. Dietary assessment

To identify dietary patterns and quantify fatty acid consumption in the study population. Dietary intake was determined by two 24-

h DR (weekday and weekend). Participants were asked to list the foods and beverages they consumed and the most common brands, portion sizes, and preparation methods. In addition, to help participants estimate their intake of different foods, a colored food atlas containing more than 100 foods and composite recipes from images of several meals and dishes commonly eaten in the Jordanian diet was used. The collected food intake was entered into a Computerized Nutrient Analysis Program: ESHA's Food Processor®, Nutrition Analysis Software (version 11:0; ESHA Research), and fatty acid intake was analyzed. Food intakes were categorized into five food groups based on World Health Organization (WHO) categories [10]. Dietary intake of macronutrients percent of requirements was assessed based on Acceptable Macronutrient Distribution Range (AMDR) [26].

2.4. Anthropometric measurements and indices

Anthropometric measurements, including height, weight, and waist circumference (WC) were taken following the standards. Participants' body weight and height were recorded to the nearest 0.1 kg and 0.1 cm, respectively, while they were only wearing minimal clothing and bare feet. A flexible anthropometric tape was used to determine the person's waist circumference while standing. This measurement was made on the horizontal plane midway between the lowest rib and the iliac crest and was rounded to the nearest 0.1 cm.

Six obesity indices were calculated in this study population: BMI, WHtR, WWI, CI, BRI, and ABSI. Traditional parameters of obesity, including BMI (kg/m^2), calculated using Quetelet's formula, and WHtR, calculated by dividing WC by height. According to BMI, participants were classified into underweight, normal, overweight, and obese according to WHO cutoff points [27]: While a WHtR cutoff of ≥ 0.5 is generally accepted as obesity [28]. The novel obesity indices were calculated using standard formulas, as presented in Table 1.

2.5. Statistical analysis

For descriptive statistics, mean $\pm$ standard deviation (SD) or stander mean of error (SEM) and percentages were used. T-test was used for continuous variables and Chi-square was used to detect differences among categorical variables. Fat patterns were derived using Principal Component Analysis and Kaiser-Meyer-Olkin (KMO-test) and Bartlett's test of sphericity was conducted to assess suitability for using factor analysis for these patterns. The commonality index was assessed to indicate the variance in each nutrient being tested by the analysis. Factors were retained based on an eigenvalue of >1.50 for the scree plot to determine the number of components/factors to extract (Fig. 1). Then Varimax rotation was applied to review the correlations between variables and factors. Sampling adequacy and inter-correlation of factors were supported by KMO value > 0.759 and Bartlett's test of sphericity <0.001, respectively. Fatty acids with absolute factor loadings >0.30 were considered to have contributed significantly to the pattern. Based on the fatty acids contributed and their sources the pattern was determined. The ranges used to convert the extracted patterns to quartiles were calculated using a frequency test. The values below 25% were defined as Q1, values between 25% and 50% were defined as Q2, values between 50% and 75% were defined as Q3, and lastly, values above 75% were defined as Q4. Linear regression models separated based on gender for each age category and adjusted for energy, fat, and fiber intake were conducted to assess the association of the selected obesity indices parameters as outcome variables and nutrient patterns as predictors. Data normality was tested by Kolmogorov–Smirnov test and the Shapiro–Wilk. Statistical analysis was performed using SPSS software (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp). The significance level was set at $p < 0.05$.

3. Results

3.1. Descriptive characteristics

The characteristics of the 1096 participants based on sex are presented in Table 2. There were significant differences between male and female participants in age ($p = 0.006$), weight ($p < 0.001$), height ($p < 0.001$), and WC ($p < 0.001$). Considering BMI, the percentage of obese male participants was significantly lower than that of female participants (18.7% vs. 23.5%; $p < 0.001$); on the contrary, the percentage of overweight males was higher than females (41.3% vs. 27.6%; $p < 0.001$). Based on WHtR, male

Table 1
Standard formulas for obesity indices.

Obesity indices	Formula	References
Weight-adjusted-waist index (WWI)	$\text{Waist circumference (cm)}/\sqrt{\text{body weight (kg)}}$	[8]
Conicity Index (CI)	$\text{Waist circumference (m)}/\left(0.109 * \sqrt{\left(\frac{\text{Weight(kg)}}{\text{height(m)}}\right)}\right)$	[5]
Body Roundness Index (BRI)	$364.2 - 365.5\sqrt{1 - \left(\frac{(\text{Waist circumference(cm)}/2\pi)^2}{(0.5 * \text{Height (cm)})^2}\right)}$	[7]
A Body Shape Index (ABSI)	$\text{Waist circumference (m)}/\left(\left(\text{Height (m)}\right)^{0.5} * \left(\text{BMI}^{\frac{2}{3}}\right)\right)$	[6]

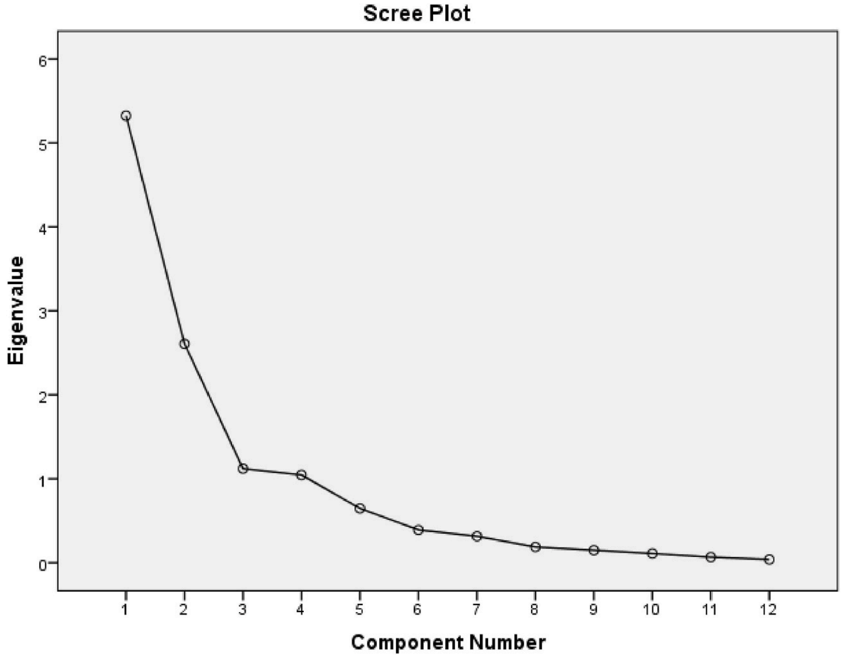

Fig. 1. Scree plot of the eigenvalues of factors and components.

Table 2
Sample's characteristics (n = 1096).

Variables	Mean ± SD		*p*-value*
	Males (n = 476)	Females (n = 620)	
Age (y)	35.00 ± 12.00	34.00 ± 11.00	0.006
Weight (kg)	81.18 ± 16.31	67.53 ± 14.30	<0.001
Height (cm)	175.17 ± 8.42	160.88 ± 6.91	<0.001
Energy (kcal)	2276.32 ± 701.14	1679.14 ± 567.83	<0.001
% Of energy from carbohydrate	48.12 ± 8.33	48.09 ± 8.25	0.962
% Of energy from protein	16.57 ± 4.66	15.74 ± 4.36	0.003
% Of energy from total fat	36.03 ± 7.42	37.19 ± 7.60	0.012
% Of energy intake from the requirement	82.51 ± 25.87	77.01 ± 26.52	0.001
% Of carbohydrate intake from the requirement	71.88 ± 24.44	66.71 ± 23.58	<0.001
% Of fiber intake from the requirement	41.29 ± 20.57	44.64 ± 23.29	0.014
% Of protein intake from the requirement	148.40 ± 62.31	124.63 ± 52.48	<0.001
% Of total fat intake from the requirement	107.42 ± 43.52	104.5 ± 47.18	0.293
% Of saturated fat intake from the requirement	64.72 ± 31.40	67.81 ± 35.85	0.137
% Of monounsaturated fat intake from the requirement	79.11 ± 47.27	73.48 ± 47.49	0.051
% Of polyunsaturated fat intake from the requirement	47.81 ± 33.29	45.85 ± 34.03	0.340
Body mass index (BMI)	26.76 ± 11.33	26.18 ± 6.12	0.276
Waist circumference (WC)	97.29 ± 63.76	83.56 ± 13.43	<0.001
Waist-to-height ratio (WHtR)	0.56 ± 0.36	0.52 ± 0.09	0.017
Weight-adjusted-waist index (WWI)	10.85 ± 7.13	10.19 ± 0.97	0.023
Conicity Index (CI)	1.32 ± 0.87	1.19 ± 0.11	<0.001
Body Roundness Index (BRI)	4.02 ± 1.79	3.90 ± 1.88	0.284
A Body Shape Index (ABSI)	11.52 ± 7.73	9.44 ± 2.83	<0.001
Body mass index (BMI) categories			
Underweight	11 (2.4)	29 (4.8)	<0.001
Normal weight	175 (37.6)	268 (44.1)	
Overweight	192 (41.3)	168 (27.6)	
Obese	87 (18.7)	143 (23.5)	
Waist-to-height ratio (WHtR)			
Normal	176 (37.0)	301 (48.6)	<0.001
Abnormal	300 (63.0)	318 (51.4)	

* *p*-value <0.05 was considered statistically significant.

participants were found to have a higher prevalence of abnormal WHtR (63.0%) compared to females (51.4%) ($p < 0.001$). Regarding the other obesity indices scores, male participants had significantly higher WWI, CI, and ABSI, except for BRI.

The mean energy intake of male participants was 2276.32 ± 701.14 kcal, with 48.12 ± 8.33% of the energy consumed from carbohydrates, 16.57 ± 4.66% from protein, and 36.03 ± 7.42% from fat. On the other hand, female participants had a mean energy intake of 1679.14 ± 567.83 kcal, of which 48.09 ± 8.25% of it consumed from carbohydrates, 15.74 ± 4.36% from protein, and 37.19 ± 7.60% from fat. Based on the requirement achievement, males had 82.51% of their energy requirement, 71.88% of their carbohydrate requirement, 41.20% of their fiber requirement, 148.40% of their protein requirement, 7.42% of their total fat requirements, 64.72% of their saturated fat (SFA) requirement, 79.11% of their monounsaturated fat (MUFA) requirement, and 47.81% of their polyunsaturated fat (PUFA) requirements. Protein and fat intake were higher than the requirements by 48.4% and 7.4% respectively. For female participants, the percentages of intakes from requirements were 77.01% for energy, 66.71% for carbohydrate, 44.64% for fiber, 124.63% for protein, 104.5% for total fat, 67.81% for SFA, 73.48% for MUFA, and 45.85% for PUFA. The intake of female participants from requirements of protein and fat was higher than recommendations by 24.6% and 4.5% respectively.

3.2. Nutrient patterns of population

Using a Principal components analysis (PCA) method, 12 fatty acids were included in the test to extract the major fatty acid patterns that met the Kaiser criterion (eigenvalues > 1.5) as seen in Fig. 1. Two major patterns have been extracted using the above-mentioned factor analysis procedure, both explaining 66.09% of the variance of dietary fatty acids consumption. These two distinct dietary fatty acid patterns are labeled the “High fatty acids from Protein and Olive Oil sources” pattern (Pattern I), and the “Low EPA and DHA” pattern (Pattern II). As illustrated in Table 3, the main fatty acids that contributed to the first nutrient pattern which was responsible for 41.78% of the total variance are mainly Palmitic acid (16:0), Heptadecanoic acid (17:0), Stearic acid (18:0), and Oleic acid (18:1). The main contributed nutrients in the second nutrient pattern which was responsible for 24.31% of the total variance were Eicosapentaenoic acid (EPA) (20:5) and Docosahexaenoic acid (DHA) (22:6) (both are omega-3 fatty acids). Fig. 1 demonstrates that only two factors met the Kaiser criterion (eigenvalues > 1.5). In contrast, ten components satisfied the same criterion. However, while performing the visual inspection of the plot, a breakpoint in the curve trajectory of the second component was suggested to meet the Kaiser criterion.

3.3. Factors association with obesity indices and MyPlate guidelines intake

Tables 4a and 4b illustrates the mean ± SEM of obesity indices score and MyPlate guidelines through the fatty acids patterns quartiles. In Table 4a, the mean ± SEM of obesity indices scores through the fatty acids patterns quartiles are presented. Regardless of gender, there were no significant differences in the obesity indices scores through the different quartiles of the two identified fatty acid patterns. Similarly, male participants had no significant differences in the obesity indices scores through the different quartiles of both identified fatty acid patterns. In contrast, among female participants, through the “Pattern I” quartiles, Q4 had a significantly lower mean score of BMI (25.12 ± 0.46; $p = 0.015$), WHtR (0.51 ± 0.01; $p = 0.002$), WWI (10.13 ± 0.09; $p = 0.021$) and BRI (3.61 ± 0.15; $p = 0.007$) compared to Q1 (BMI = 27.28 ± 0.47, WHtR = 0.54 ± 0.01, WWI = 10.36 ± 0.07, and BRI = 4.27 ± 0.15). While through “Pattern II” quartiles, Q4 had significantly higher scores means of WC (86.28 ± 1.34) and ABSI (10.12 ± 0.30) in comparison to Q1 (WC = 81.55 ± 1.08 and ABSI = 9.07 ± 0.22; $p = 0.025$, 0.013; respectively).

The mean ± SEM of the MyPlate food group’s servings through the fatty acids patterns quartiles are shown in Table 4b. Based on MyPlate guidelines, in general, for “Pattern I ”, the participant in Q4 had a significantly higher intake of grain (6.38 ± 0.21oz-e; $p < 0.001$), dairy (0.43 ± 0.02c; $p < 0.001$), protein (8.35 ± 0.25oz-e; $p < 0.001$), and it was almost significant for vegetables (0.77 ±

Table 3
Factor loading matrix and explained variances for the two identified fatty acids patterns in the study sample (n = 1096).

Fatty acids (components)	Fatty acid patterns	
	“Pattern I”	“Pattern II”
1. Myristic acid (14:0)	0.675	
2. Palmitic acid (16:0)	**0.964**	
3. Heptadecanoic acid (17:0)	0.541	
4. Stearic acid (18:0)	**0.942**	
5. Palmitol acid (16:1)	0.769	0.319
6. Oleic acid (18:1)	**0.845**	
7. Linoleic acid (18:2)	0.771	
8. Linolenic acid (18:3)	0.719	
9. Stearidonic acid (18:4)		0.719
10. Eicosapentaenoic acid (EPA) (20:5)		**0.914**
11. Docosapentaenoic acid (DPA) (22:5)		0.715
12. Docosahexaenoic acid (DHA) (22:6)		**0.939**
Explained variance %	**41.778**	**24.309**
Cumulative explained variance %	**41.778**	**66.087**

Bold factor loadings are used to indicate factor loadings ≥ 0.80 were used for naming the nutrient patterns.

Table 4a
Mean ± SEM of obesity indices score, and MyPlate guidelines, through the fatty acids patterns quartiles: obesity indices.

Obesity indices	PCA1					PCA2				
	Q1	Q2	Q3	Q4	p-value*	Q1	Q2	Q3	Q4	p-value*
	Total									
Body mass index (BMI)	26.97 ± 0.37	26.23 ± 0.38	26.64 ± 0.87	25.89 ± 0.29	0.500	26.74 ± 0.92	26.06 ± 0.31	26.13 ± 0.29	26.81 ± 0.34	0.646
Waist circumference (WC)	90.96 ± 3.52	89.33 ± 2.35	86.66 ± 0.85	91.20 ± 3.09	0.599	86.10 ± 0.88	89.82 ± 3.49	89.46 ± 2.33	92.75 ± 3.09	0.366
Waist-to-height ratio (WHtR)	0.55 ± 0.02	0.54 ± 0.01	0.52 ± 0.01	0.54 ± 0.02	0.424	0.52 ± 0.01	0.54 ± 0.02	0.54 ± 0.01	0.55 ± 0.02	0.571
Weight-adjusted-waist index (WWI)	10.67 ± 0.35	10.54 ± 0.29	10.16 ± 0.06	10.55 ± 0.35	0.610	10.16 ± 0.06	10.60 ± 0.35	10.57 ± 0.29	10.59 ± 0.35	0.646
Conicity Index (CI)	1.25 ± 0.04	1.25 ± 0.04	1.21 ± 0.01	1.26 ± 0.04	0.665	1.20 ± 0.01	1.25 ± 0.04	1.25 ± 0.04	1.27 ± 0.04	0.603
Body Roundness Index (BRI)	4.17 ± 0.12	3.95 ± 0.11	3.87 ± 0.12	3.82 ± 0.09	0.126	3.89 ± 0.13	3.90 ± 0.10	3.95 ± 0.10	4.06 ± 0.11	0.675
A Body Shape Index (ABSI)	10.60 ± 0.47	10.25 ± 0.27	10.01 ± 0.19	10.52 ± 0.37	0.601	9.94 ± 0.20	10.30 ± 0.46	10.23 ± 0.26	10.91 ± 0.37	0.225
	Males									
Body mass index (BMI)	26.31 ± 0.54	26.38 ± 0.46	27.91 ± 1.91	26.40 ± 0.36	0.649	28.55 ± 2.09	26.43 ± 0.46	25.79 ± 0.45	26.37 ± 0.35	0.285
Waist circumference (WC)	102.43 ± 10.85	99.29 ± 5.88	92.23 ± 1.10	97.11 ± 5.03	0.702	92.74 ± 1.25	101.46 ± 9.14	97.64 ± 5.77	97.61 ± 5.29	0.801
Waist-to-height ratio (WHtR)	0.58 ± 0.06	0.57 ± 0.03	0.53 ± 0.01	0.55 ± 0.03	0.759	0.53 ± 0.01	0.58 ± 0.05	0.56 ± 0.03	0.56 ± 0.03	0.865
Weight-adjusted-waist index (WWI)	11.34 ± 1.10	11.14 ± 0.76	10.30 ± 0.09	10.83 ± 0.58	0.729	10.27 ± 0.11	11.20 ± 0.93	11.09 ± 0.75	10.88 ± 0.61	0.778
Conicity Index (CI)	1.38 ± 0.14	1.35 ± 0.09	1.25 ± 0.01	1.32 ± 0.07	0.718	1.24 ± 0.01	1.36 ± 0.12	1.35 ± 0.09	1.32 ± 0.07	0.765
Body Roundness Index (BRI)	3.93 ± 0.19	4.09 ± 0.17	4.11 ± 0.19	3.95 ± 0.12	0.816	4.21 ± 0.22	3.97 ± 0.16	3.93 ± 0.16	3.97 ± 0.12	0.620
A Body Shape Index (ABSI)	12.19 ± 1.39	11.67 ± 0.61	10.99 ± 0.29	11.47 ± 0.58	0.741	11.22 ± 0.33	12.11 ± 1.17	11.29 ± 0.60	11.51 ± 0.60	0.839
	Females									
Body mass index (BMI)	27.28 ± 0.47	26.14 ± 0.54	25.64 ± 0.41	25.12 ± 0.46	0.015	25.51 ± 0.57	25.83 ± 0.41	26.35 ± 0.38	27.39 ± 0.63	0.065
Waist circumference (WC)	85.65 ± 1.01	83.24 ± 0.97	82.28 ± 1.14	82.32 ± 1.20	0.073	81.55 ± 1.08	82.91 ± 1.01	84.29 ± 0.95	86.28 ± 1.34	0.025
Waist-to-height ratio (WHtR)	0.54 ± 0.01	0.52 ± 0.01	0.51 ± 0.01	0.51 ± 0.01	0.002	0.51 ± 0.01	0.52 ± 0.01	0.53 ± 0.01	0.53 ± 0.01	0.084
Weight-adjusted-waist index (WWI)	10.36 ± 0.07	10.18 ± 0.07	10.05 ± 0.08	10.13 ± 0.09	0.021	10.08 ± 0.08	10.24 ± 0.07	10.24 ± 0.07	10.21 ± 0.09	0.373
Conicity Index (CI)	1.20 ± 0.01	1.18 ± 0.01	1.17 ± 0.01	1.18 ± 0.01	0.212	1.17 ± 0.01	1.19 ± 0.01	1.19 ± 0.01	1.19 ± 0.01	0.434
Body Roundness Index (BRI)	4.27 ± 0.15	3.86 ± 0.14	3.68 ± 0.15	3.61 ± 0.15	0.007	3.67 ± 0.16	3.85 ± 0.14	3.97 ± 0.13	4.18 ± 0.19	0.139
A Body Shape Index (ABSI)	9.87 ± 0.23	9.38 ± 0.20	9.24 ± 0.23	9.10 ± 0.24	0.087	9.07 ± 0.22	9.23 ± 0.21	9.56 ± 0.19	10.12 ± 0.30	0.013

PCA1 = Pattern I; PCA2 = Pattern II.
* Statistically significant at $p < 0.05$.

0.04c; $p = 0.056$) in comparison to Q1 participants (grain = 4.56 ± 0.19 oz-e; dairy = 0.24 ± 0.03c; vegetables = 0.62 ± 0.05c; and protein = 3.05 ± 0.15 oz-e). For the "Pattern II", the participants in Q4 had a significantly higher intake of grain (6.10 ± 0.21oz-e; $p = 0.002$), vegetables (0.79 ± 0.05c; $p = 0.028$), fruit (0.89 ± 0.08c; $p = 0.041$) and protein (8.04 ± 0.24 oz-e; $p < 0.001$) comparing to Q1 (Grain = 5.40 ± 0.23oz-e; vegetables = 0.60 ± 0.04c; fruit = 0.86 ± 0.06 c; and protein = 3.85 ± 0.18 oz-e). Moreover, based on gender, male participants in Q4 of "Pattern I" had significantly higher grain (7.15 ± 0.29 oz-e; $p = 0.046$), dairy (0.43 ± 0.03c; $p < 0.001$) and protein (9.13 ± 0.33oz-e; $p < 0.001$) intake, in contrast to Q1 participants who had lower grain (55.83 ± 0.45 oz-e), dairy (0.22 ± 0.03c) and protein (0.29 ± 0.03 oz-e) intake based on MyPlate recommendations. On the other hand, participants in Q4 of "Pattern II", only had a significantly higher protein intake (9.15 ± 0.34 oz-e) compared to Q1 participants (4.59 ± 0.32 oz-e) ($p < 0.001$). Likewise, female participants in Q4 of "Pattern I" had significantly higher grain (5.23 ± 0.26 oz-e; $p < 0.001$), protein intake (7.19 ± 0.36 oz-e; $p < 0.001$), and near significant higher dairy intake (0.42 ± 0.04c; $p = 0.05$), in contrast to Q1 participants who had lower grain (3.98 ± 0.18 oz-e), protein (2.82 ± 0.16oz-e) and dairy (0.25 ± 0.04c) intake based on MyPlate guidelines recommended serving numbers. And participants in Q4 of the tern II", only had a significantly higher protein intake (6.56 ± 0.26 oz-e) compared to Q1 participants (3.35 ± 0.21 oz-e) ($p < 0.001$).

Table 5 shows the multivariable linear regression models analysis of the association of obesity indices indicators (BMI, WC, WHtR,

Table 4b
Mean ± SEM of obesity indices score, and MyPlate guidelines through the fatty acids patterns quartiles: MyPlate.

	PCA1					PCA2				
	Q1	Q2	Q3	Q4	*p- value**	Q1	Q2	Q3	Q4	*p- value**
	Total									
Grain (oz-e)	4.56 ± 0.19	5.10 ± 0.21	5.77 ± 0.22	6.38 ± 0.21	**<0.001**	5.40 ± 0.23	5.00 ± 0.19	5.33 ± 0.20	6.10 ± 0.21	**0.002**
Vegetables (c)	0.62 ± 0.05	0.69 ± 0.05	0.78 ± 0.05	0.77 ± 0.04	**0.056**	0.60 ± 0.04	0.71 ± 0.05	0.76 ± 0.05	0.79 ± 0.05	**0.028**
Fruit (c)	0.75 ± 0.07	0.74 ± 0.05	0.87 ± 0.07	0.92 ± 0.07	0.123	0.86 ± 0.06	0.66 ± 0.05	0.87 ± 0.07	0.89 ± 0.08	**0.041**
Dairy (c)	0.24 ± 0.03	0.31 ± 0.03	0.38 ± 0.03	0.43 ± 0.02	**<0.001**	0.38 ± 0.03	0.28 ± 0.02	0.33 ± 0.02	0.36 ± 0.03	0.105
Protein (oz-e)	3.05 ± 0.15	4.31 ± 0.16	5.40 ± 0.17	8.35 ± 0.25	**<0.001**	3.85 ± 0.18	3.92 ± 0.20	5.29 ± 0.17	8.04 ± 0.24	**<0.001**
	Males									
Grain (oz-e)	5.83 ± 0.45	6.74 ± 0.44	7.33 ± 0.36	7.15 ± 0.29	**0.046**	6.98 ± 0.42	6.40 ± 0.40	6.86 ± 0.39	7.09 ± 0.30	0.600
Vegetables (c)	0.55 ± 0.10	0.63 ± 0.07	0.73 ± 0.06	0.76 ± 0.06	0.142	0.58 ± 0.06	0.70 ± 0.09	0.72 ± 0.07	0.74 ± 0.05	0.357
Fruit (c)	0.79 ± 0.14	0.73 ± 0.08	0.80 ± 0.10	0.87 ± 0.11	0.786	0.87 ± 0.11	0.60 ± 0.09	0.84 ± 0.10	0.88 ± 0.11	0.251
Dairy (c)	0.22 ± 0.03	0.29 ± 0.03	0.43 ± 0.04	0.43 ± 0.03	**<0.001**	0.38 ± 0.04	0.32 ± 0.03	0.35 ± 0.03	0.38 ± 0.03	0.460
Protein (oz-e)	3.55 ± 0.31	5.03 ± 0.31	5.84 ± 0.29	9.13 ± 0.33	**<0.001**	4.59 ± 0.32	4.51 ± 0.35	6.00 ± 0.29	9.15 ± 0.34	**<0.001**
	Females									
Grain (oz-e)	3.98 ± 0.18	4.10 ± 0.15	4.54 ± 0.21	5.23 ± 0.26	**<0.001**	4.31 ± 0.21	4.16 ± 0.17	4.36 ± 0.19	4.78 ± 0.23	0.213
Vegetables (c)	0.65 ± 0.06	0.72 ± 0.07	0.81 ± 0.07	0.79 ± 0.06	0.273	0.61 ± 0.06	0.72 ± 0.05	0.78 ± 0.07	0.85 ± 0.09	0.080
Fruit (c)	0.74 ± 0.08	0.75 ± 0.07	0.93 ± 0.09	1.00 ± 0.08	0.062	0.85 ± 0.07	0.70 ± 0.06	0.89 ± 0.09	0.92 ± 0.11	0.194
Dairy (c)	0.25 ± 0.04	0.32 ± 0.05	0.34 ± 0.04	0.42 ± 0.04	**0.056**	0.37 ± 0.05	0.26 ± 0.02	0.32 ± 0.04	0.33 ± 0.07	0.327
Protein (oz-e)	2.82 ± 0.16	3.86 ± 0.18	5.05 ± 0.20	7.19 ± 0.36	**<0.001**	3.35 ± 0.21	3.58 ± 0.23	4.85 ± 0.20	6.56 ± 0.26	**<0.001**

PCA1 = Pattern I; PCA2 = Pattern II; oz-e: ounce; c: cup.
* Statistically significant at $p < 0.05$.

WWI, CI, BRI, and ABSI; as outcome variables) with the two fatty acid patterns (predictor variables) and possible confounding factors (gender, energy intake, total fat intake, and fiber intake). For the total sample and after adjustment for gender, energy intake, total fat intake, and fiber intake, there was only a statistically significant association between "Pattern I" with BRI and ABSI. A one standard deviation increases in the "Pattern I" resulted in a 0.19 ($p = 0.002$) and 0.39 ($p = 0.034$) decrease in BRI and ABSI, respectively.

Based on gender and after adjusting for energy intake, total fat intake, and fiber intake, male participants had no statistically significant association between the two fatty acid patterns and any of the obesity indices. In contrast, female adult participants had statistically significant associations between "Pattern I" and all the obesity indices. Increasing this pattern by one standard deviation resulted in a 0.82 decrease in BMI ($p = 0.003$), a 1.80 cm decrease in WC ($p = 0.003$), a 0.02 decrease in WHtR ($p < 0.001$), a 0.16 cm/kg$^{1/2}$ decrease in WWI ($p < 0.001$), a 0.01 decrease in CI ($p = 0.007$), a 0.32 decrease in BRI ($p < 0.001$), and a 0.34 decrease in ABSI ($p = 0.009$). Additionally, female participants had a significant statistical association between "Pattern II" and most of the obesity indices. Where increasing this pattern by one standard deviation leads to a 0.69 increase in BMI ($p = 0.003$), 1.56 cm increase in WC ($p = 0.002$), 0.01 increase in WHtR ($p = 0.010$), 0.17 increase in BRI ($p = 0.020$), and 0.36 increase in ABSI ($p = 0.001$).

4. Discussions

With the rising prevalence of obesity globally, the importance of considering risk factors has grown. One of these factors is the nutrient composition of consumed foods. The global dietary intake has shifted to a Westernized diet, which is characterized by an increase in fast food, processed food, total fat intake, and consumption of added sugars and added fats [29,30]. The current study sought to identify Jordanian adults' fatty acid patterns based on dietary fat intake and to determine the relationship between the obtained patterns and obesity indices.

In the present study, the mean BMI for males and females was 26.76 ± 11.33, and 26.18 ± 6.12 kg/m^2, respectively. Regarding non-classical novel obesity indices, male participants had significantly higher scores for all indices except for BRI (WHtR: 0.56 ± 0.36; WWI: 10.85 ± 7.13; CI: 1.32 ± 0.87; BRI: 4.02 ± 1.79; and ABSI: 11.52 ± 7.73) compared to female participants. According to BMI, the prevalence of obesity among male participants was 18.7%, which was significantly lower than that of female participants (23.5%). At the same time, the prevalence of overweight in male participants (41.3%) was higher than in female participants (27.6%). Based on

Table 5
Multivariable linear regression models showing the association of obesity indices indicators (BMI, WC, WHtR, WWI, CI, BRI, and ABSI; outcome variables) with the two fatty acid patterns (predictor variables) and possible confounding factors (Gender, and total energy, total fat, and fiber intakes).

	Nutrient pattern	BMI		WC		WHtR		WWI		CI		BRI		ABSI	
		Adjusted β (95% CI)	p-Value	Adjusted β (95% CI)	p-Value	Adjusted β (95% CI)	p-Value	Adjusted β (95% CI)	p-Value	Adjusted β (95% CI)	p-Value	Adjusted β (95% CI)	p-Value	Adjusted β (95% CI)	p-Value
Total sample	PCA 1	−0.38 (−0.96; 0.19)	0.189	−2.40 (−5.23; 0.43)	0.097	−0.02 (−0.03; 0.00)	0.060	−0.20 (−0.51; 0.11)	0.209	−0.02 (−0.06; 0.02)	0.249	**−0.19 (−0.31; -0.07)**	**0.002**	**−0.39 (−0.75; -0.03)**	**0.034**
	PCA2	0.08 (−0.39; 0.56)	0.731	1.25 (−1.09; 3.60)	0.293	0.01 (−0.01; 0.02)	0.343	0.08 (−0.7; 0.34)	0.519	0.01 (−0.02; 0.04)	0.493	0.06 (−0.04; 0.16)	0.218	0.19 (−0.11; 0.49)	0.205
Males	PCA 1	0.13 (−0.97; 1.23)	0.814	−3.30 (−9.47; 2.87)	0.294	−0.02 (−0.05; 0.02)	0.360	−0.28 (−0.97; 0.41)	0.428	−0.04 (−0.12; 0.05)	0.395	(−0.04 (−0.21; 0.14)	0.669	−0.46 (−1.21; 0.28)	0.223
	PCA2	−0.59 (−1.48; 0.30)	0.190	0.77 (−4.23; 5.77)	0.762	0.00 (−0.02; 0.03)	0.829	0.12 (−0.44; 0.68)	0.665	0.02 (−0.05; 0.08)	0.655	−0.06 (−0.20; 0.08)	0.430	−0.01 (−0.61; 0.60)	0.984
Females	PCA 1	**−0.82 (−1.36; -0.28)**	**0.003**	**−1.80 (−2.99; -0.60)**	**0.003**	**−0.02 (−0.02; -0.01)**	**<0.001**	**−0.16 (−0.24; -0.07)**	**<0.001**	**−0.01 (−0.02; 0.00)**	**0.007**	**−0.32 (−0.48; -0.15)**	**<0.001**	**−0.34 (−0.59; -0.09)**	**0.009**
	PCA2	**0.69 (0.23;1.14)**	**0.003**	**1.56 (0.56; 2.57)**	**0.002**	**0.01 (0.00; 0.02)**	**0.010**	0.03 (−0.04; 0.10)	0.382	0.00 (0.00; 0.01)	0.251	**0.17 (0.03; 0.31)**	**0.020**	**0.36 (0.15; 0.57)**	**0.001**

PCA1 = Pattern I; PCA2 = Pattern II.
* Statistically significant at $p < 0.05$.

the WHtR, male participants had a higher prevalence of abnormal WHtR (63.0%) compared to females (51.4%). It reflected central obesity rather than generalized obesity, like BMI, and was consistent with Ajlouni and colleagues' findings (2020), where they reported that 60.4% of men and 75.6% of women were overweight or obese in Jordan [31].

Based on the requirement, both males and females did not consume adequate daily needs from total energy, carbohydrates, fibers, SFA, MUFA, and PUFA. Despite that, both genders consumed higher amounts of protein, and total fat, that exceeded their daily requirements (males' protein and fat intake were higher than the requirement by 48.4% and 7.4%, respectively, while the intake of female participants from needed protein and fat was higher by 24.6% and 4.5%, respectively). Given that insufficient/or borderline daily energy intake for the majority of participants (regardless of gender), note that the estimated average daily caloric need for American females and males is about (1600–2200 calories) and (2200–3000 calories), respectively [32], the overweight and/or obesity prevalence was high among study participants. This was to reflect that rather than total energy intake is the primary concern in obesity prevention, the necessary nutritional components of a healthy diet, such as fiber, MUFA, and/or PUFAs, and essential amino acids, play an important role in obesity prevention [33]. The factors that influence obesity phenotypes, including the importance of diet composition, or the amount of food consumed as measured by food groups (food-based categories) or nutrients (macro/-micronutrients), and activity-related behaviors, such as the amount of time spent sleeping, watching television, and engaging in other sedentary activities, as well as physical activity showed uncertainty [34]. Also, high-fat diets (that exceed the daily requirements amount of fat intake) have been approved to increase weight/obesity, systematic inflammation, and impaired glucose tolerance [33].

Remarkably, monitoring the type of fat consumed may be more crucial for obesity management than overall fat consumption. Since some sources of fat are known to be more harmful than others, they can exacerbate metabolic deficits caused by obesity [35]. SFA is substantially more inflammatory than unsaturated fat and has been known to interfere directly with insulin signals [35,36].

As fat intake exceeded the daily requirements, this finding may lead to a better understanding of dietary fatty acid patterns for the study population. The two distinct dietary fatty acid patterns, labeled "Pattern I" and "Pattern II" were extracted. Those two patterns reflected Jordanians' cultural and traditional eating habits, as they consumed fewer amounts of seafood (such as fatty fish and marine fish), soybean oil, and flaxseed oil as major dietary sources of EPA and DHA [37]. However, higher amounts of olive oil have been consumed, as a source of Oleic acid, in addition to safflower, sesame, and pumpkin seeds. Also, the high consumption of palmitic acid, stearic acid, and heptadecanoic acid by Jordanians maybe come from the consumption of meat, milk, milk fat, dairy product, and butter [38,39].

Among female participants, through the "Pattern I" quartiles, Q4 had a significantly lower mean of BMI (25.12 ± 0.46), WHtR (0.51 ± 0.01), WWI (10.13 ± 0.09), and BRI (3.61 ± 0.15) compared to Q1. Consistency with the present findings and according to the literature, high-protein diets prevent weight gain and maintenance [40]. Several studies considering the protein source reported a negative correlation between consuming plant protein and the risk of being obese [41,42]. Dairy products may also help reduce weight gain because they contain calcium and branched-chain amino acids, which may work together to control body fat during developmental stages [43,44]. Notably, the fatty acid composition of diets has been shown to impact their obesogenic profile and overall toxicity [45]. In particular, a diet high in SFAs causes more body fat to accumulate and reduces satiety than diets richer in PUFAs; In line with the present findings about Oleic acid as MUFA, and according to Paniagua González and colleagues (2007), MUFA-rich diets prevent a postprandial decline in the peripheral adiponectin gene expression [46]. It regulates energy metabolism through interactions with glucose and insulin, stimulating fatty acid oxidation, lowering plasma triglycerides, and improving glucose metabolism by increasing insulin sensitivity [47]. Moreover, MUFA consumption is associated with reduced effects of obesity and its related metabolic syndromes, particularly extra virgin olive as a source of MUFAs, which increased the gut microbiota diversity of healthy and unhealthy animal models, including humans at risk of metabolic syndrome [48].

The present study indicated that the "Pattern II" quartiles, Q4 had significantly higher means of WC (86.28 ± 1.34) and ABSI (10.12 ± 0.30 m) in comparison to Q1 in females. The nutritional transition observed worldwide in the past few decades has introduced high amounts of SFAs and omega-6 PUFAs in the human diet through increased intake of dairy products, vegetable oils, and red meat. This change in dietary profile was further accompanied by a reduction in the consumption of fruits, vegetables, legumes, grains, and fish, important sources of omega-3 PUFAs [45]. Notably, the effect of PUFAs dietary intake on obesity and obesity indices has been discussed in much research. According to Micallef and colleagues' (2009) study, obese women's BMI, WC, and hip circumference all had an inverse relationship with their levels of omega-3 PUFA, (especially EPA, and DHA) [49]. However, the balance of omega-3 and omega-6 PUFAs is crucial in both the prevention and treatment of obesity, according to scientific research. Increased omega-3 PUFA consumption (a lower omega-6/omega-3 ratio) exerts suppressive effects, whereas excessive omega-6 PUFA intake and a high omega-6/omega-3 ratio promote the pathogenesis of many diseases, including cardiovascular disease, cancer, obesity, and inflammatory and autoimmune diseases [50]. In both animal and human research, high levels of circulating omega-6 PUFA (high n-6/omega-3 PUFA ratios; common for Western diets) are linked to weight gain and obesity, but high levels of omega-3 PUFA (lower omega-6/omega-3 PUFA ratio) are positively correlated with an obese phenotype [51]. Additionally, Del Pozo and colleagues (2020) showed that BMI was positively correlated with the relative concentration of SFA, but they are negatively correlated with oleic, gondoic, *trans*-vaccenic, linoleic, and γ-linolenic acids. Also, they reported that low relative concentrations of some SFAs and high levels of omega-6 PUFAs have been associated with a greater WC [52]. Human dietary intervention trials suggest that fish oil (EPA and DHA) supplementation might decrease WC and adiposity by starting AMP-activated protein kinase, which in turn actives fatty oxidation in adipose tissue [53]. EPA and DHA are also promoting mitochondrial biogenesis, leading to increase energy metabolism, meditating increment in fatty acid oxidation, and decrease lipogenesis which could be accountable for their anti-obesity actions [54,55]. Furthermore, omega-3 fatty acid could decrease body weight, by improving the metabolic profile through various mechanisms including alteration in adipokines release; modification of gene expression in adipose tissue; adipokine-mediated or adipokine-connected pathways; variation in the carbohydrate metabolism; appetite suppression; rise in fat oxidation; intensification in energy expenditure (probably by thermogenesis); initiation of mechanisms related to muscle anabolism; and, lastly, epigenetic actions [53].

The females in Q4 of "Pattern I" had a higher intake of grain, protein, and dairy intake, in contrast to Q1 participants. Based on MyPlate, in general, for both patterns, the participant in Q4 had a significantly higher intake of grain, dairy, vegetables, and protein in comparison to Q1 participants. In the total population, there was a statistically significant association between "Pattern I" with BRI and ABSI. One standard deviation increases in "Pattern I" resulted in a 0.19 and 0.39 decrease in BRI and ABSI scores, respectively. In numerous studies, the relationship between dietary patterns and obesity has been examined. In Japanese women (18–20 years), it has been observed that the 'Healthy' pattern (characterized by high intakes of vegetables, mushrooms, seaweeds, potatoes, fish and shellfish, soy products, processed fish, fruit, and salted vegetables) was significantly associated with a lower risk of BMI (odds ratio of the highest quintile vs lowest, 0.57; 95% confidence interval: 0.37–0.87). In contrast, the 'Japanese traditional' pattern (characterized by high intakes of rice, miso soup, and soy products, and the 'Western' pattern, characterized by high intakes of meats, fats, oils, seasonings, processed meats, and eggs, were both significantly associated with an increased risk of BMI (OR: 1.77; 95% CI: 1.17–2.67; and OR: 1.56; 95% CI: 1.01–2.40; respectively) [56].

Besides, it has been approved that the dietary patterns characterized by a frequent intake of refined cereals, red meat, processed foods, and low intake of fruits and vegetables, known as the "Western" diet, is associated with a higher prevalence and incidence of overweight and obesity, CVD, T2DM, and cancer [57,58]. Western societies experienced drastic changes in eating habits during the past century. The modern nutritional profile, typically rich in saturated fats and refined sugars, is recognized as a major contributing factor, along with reduced physical activity, to the current epidemics of metabolic disorders, notably obesity and T2DM [45]. In Indian adults, three dietary patterns were identified: 'cereals–savory foods' (cooked grains, rice/rice-based dishes, snacks, condiments, soups, nuts), 'fruit–veg– sweets–snacks' (Western cereals, vegetables, fruit, fruit juices, cooked milk products, snacks, sugars, sweets) and 'animal-food' (red meat, poultry, fish/seafood, eggs). In adjusted analysis, positive graded associations were found between the 'animal-food' pattern and both anthropometric risk factors. Moderate intake of the 'cereals–savory foods' pattern was associated with reduced odds of obesity and central obesity [12]. In a prospective population-based cohort study with two surveys 12 years apart in Sweden's rural areas in men aged 40–60 years, it has been approved that a low intake of dairy fat at baseline (no butter and low-fat milk and seldom/never whipping cream) was associated with a higher risk of developing central obesity (expressed by WHtR) (OR 1.53, 95% CI 1.05–2.24 [59]. Also, a high intake of dairy fat (butter as spread and high-fat milk and whipping cream) was associated with a lower risk of central obesity (OR 0.52, 95% CI 0.33–0.83) as compared with medium intake (all other combinations of spread, milk, and cream) [59]. Parallel to that, it has been demonstrated that several food categories, such as fruits, vegetables, and fish, have a preventive impact on obesity [60].

In the current study, a significant association between "Pattern I" and all the obesity indices was obvious among female participants. The increase of this pattern by one standard deviation resulted in a 0.82 decrease in BMI, a 1.80 cm decrease in WC, a 0.02 decrease in WHtR, a 0.16 decrease in WWI, a 0.01 decrease in CI, a 0.32 decrease in BRI, and a 0.34 decrease in ABSI. Additionally, female participants had a significant statistical association between "Pattern II" and most of the obesity indices. Where increasing this pattern by one standard deviation leads to a 0.69 increase in BMI, 1.56 increase in WC, 0.01 increase in WHtR, 0.17 increase in BRI, and 0.36 increase in ABSI. Sex-specific correlations have been noticed in many studies, and numerous research has examined how gender disparities in eating patterns and disease risk differ, with varying degrees of success. In the Mexican adult population, they identified a Rural pattern characterized by tortilla, legumes, and egg consumption; a Diverse pattern, characterized by fruits, meat and poultry, vegetables, dairy beverages, and desserts; and a Westernized pattern, characterized by sweetened non-dairy beverages, fast food, bakery, and cookies, candies and salty snacks. In men, the Westernized pattern was associated with overweight/obesity (PR = 1.11, 95% CI 0.97–1.27), and abdominal obesity (PR = 1.15, 95% CI 1.00–1.33), the Diverse pattern was associated with overweight-obesity (PR = 1.18, 95% CI 1.00–1.38), and abdominal obesity (PR = 1.27, 95%CI 1.07–1.50), compared with the Rural pattern. In women, these dietary patterns were not associated with obesity [15]. Yuan and colleagues (2016) examined gender differences in middle-aged and elderly populations in Shanghai. They identified four dietary patterns (rice staple, wheat staple, snacks, and prudent patterns), and they discovered disparities in the relationship between food habits and obesity by gender. While the pattern of rice consumption was connected inversely with overall obesity in women, it was positively associated with abdominal obesity in males. But the incidence of central obesity was considerably higher for men in the higher quartile of the wheat staple pattern [61]. In middle-aged participants in Taiwan, Lin and colleagues (2019) found that both men and women in the highest quartile of the Western dietary pattern had a significantly increased odds ratio of general obesity, central obesity, and high body fat. However, only male subjects in the higher quartiles of the prudent dietary pattern (containing higher intakes of dark- or light-colored vegetables, fruits, vegetables with oil or dressing, root crops, seafood, legumes, dairy products, milk, rice and flour products, and whole grains) had a significantly decreased odds ratio of all indices of obesity [41,42]. Also, Yammine et al. (2018) found a divergent correlation concerning sex between individuals' omega-6 and omega-3 PUFAs and BMI values. In men, omega-3 α-linolenic acid, an essential fatty acid from the omega-3 family, tended to be positively correlated with obesity ($r = 0.18$, $p = 0.04$), while DHA was negatively correlated with it ($r = -0.24$, $p = 0.009$). In women, omega-6 γ-linoleic acid ($r = 0.17$, $p = 0.006$) and EPA ($r = 0.14$, $p = 0.02$) were positively correlated with BMI. Besides all fatty acids significantly correlated with obesity indices showed a significant linear relationship with BMI and waistline, there was no significant relationship between BMI or waistline and all other individual fatty acids such as pentadecanoic acid (C15:0), heptadecanoic acid (C17:0), and most of the omega-6 fatty acids, and omega-3 PUFAs [62]. The above-mentioned correlations, which have been found in females in the present study, were not reflected in male participants and had been introduced. Therefore, future research to verify and validate these associations are required.

Strength and limitation: One of the main advantages of the current study is that, as far as we know, it is the first one to investigate fatty acid patterns in Jordan and other Arab nations. The second strength was a sizable representative sample taken from a population-based study and stringent data quality control techniques that minimized inaccurate dietary consumption reporting. Third, a skilled nutritionist collected anthropometric measures using established techniques and evaluate overweight and obesity using traditional and cutting-edge indices. Additionally, the outcomes of this study reflect the COVID-19 pandemic afterward. Among study limitations, the cross-sectional design of the study was one of its shortcomings since it is impossible to observe causal effects. Inadequate biochemical information about blood lipid profiles, serum fatty acid profile, blood sugar, and, last but not least, omitted confounding factors such as physical activity, employment status, education, sleep hygiene, and smoking status.

5. Conclusion

Given that the total energy intake was lower than the daily recommendations in the majority of the study participants, protein and fat intake were higher than the recommendations. Monitoring the type of fat consumed may be more crucial for obesity management than overall fat consumption. Since some sources of fat are known to be more harmful than others, they can exacerbate obesity, and affect obesity indices. Among distinguished dietary patterns, in contrast to "Pattern II", which had a detrimental association with obesity indices, "Pattern I" appeared to be obesity preventative. Notably, females were more likely than males to have the aforementioned relationships. Dietary guidelines may include restricting intakes of foods high in certain fatty acid types in favor of sources of EPA and DHA. Additional studies exploring longitudinal changes in obesity-related fatty acid patterns unique to the Jordanian setting are required to further explain and build on the relationships found in the present investigation.

Ethics approval and consent to participate

The study was approved by The Hashemite University's Institutional Board Review (IRB) committee (No.7/13/2020/2021). Written, informed consent was obtained from the patient's parents to publish this manuscript.

Author contribution statement

Lana Agraib: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.
Huda Al Hourani: Conceived and designed the experiments; Performed the experiments; Wrote the paper.
Islam Al-Shami: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.
Buthaina Alkhatib: Performed the experiments; Wrote the paper.
Ayoub Al-Jawaldeh: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

Data availability statement

Data included in article/supp. material/referenced in article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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