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The relationship between adherence to the Mediterranean diet and abdominal obesity and related metabolic risk

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ABSTRACT

Introduction: The Mediterranean diet is rich in bioactive compounds that have protective effects against metabolic disorders, and insulin resistance and reduce weight.

Objective: To explore the relationship between adherence to the Mediterranean diet and central obesity as well as related metabolic disorders.

Material and Methods: A cross-sectional study was conducted on 480 participants between the ages (18 - 65) years who were diagnosed with metabolic disorders. Data was collected using a structured questionnaire to determine socio-demographic data, anthropometric measurements, and biochemical laboratory results of metabolic parameters. The Mediterranean Diet Adherence Screener was used to measure the adherence of participants to the Mediterranean Diet. Pearson correlation and multiple linear regression were used to measure the strength and magnitude of association between parameters.

Results: The Pearson correlation analysis demonstrates a significant negative correlation between the Mediterranean dietary score and triglyceride levels ($r = -0.689$, $p < 0.001$), HbA1c ($r = -0.63$, $p < 0.001$), and a significant positive correlation with HDL cholesterol levels ($r = 0.746$, $p < 0.001$). The results of multiple linear regression indicate that higher adherence to the Mediterranean Diet is significantly and inversely associated with triglycerides ($B = -0.244$, $p < 0.001$), total cholesterol ($B = -0.180$, $p < 0.001$), HbA1c ($B = -0.031$, $p < 0.001$), and waist-hip ratio ($B = -0.065$, $p < 0.001$). Additionally, HDL cholesterol levels are predicted to increase by 0.512 units ($p < 0.001$) for each unit increase in the Mediterranean diet score.

Conclusion: Adherence to the Mediterranean Diet could lead to a more favorable cardiovascular and metabolic risk profile. Adherence to the Mediterranean diet should be considered a key aspect of public health nutritional strategies to control the increasing prevalence of obesity and metabolic disorders.

KEYWORDS

Mediterranean Diet, eating style, metabolic syndrome, anthropometric measurement, obesity.

ABBREVIATIONS

PUFAs: Polyunsaturated fatty acids.

MUFAs: Monounsaturated fatty acids

WHR: Waist-hip ratio.

BMI: Body mass index.

MEDAS-14: Mediterranean Diet Adherence Screener- 14.

HDL- cholesterol: High-density lipoproteins.

LDL- cholesterol: Low-density lipoproteins.

HbA1c: Glycated hemoglobin.

INTRODUCTION

The prevalence of obesity and metabolic disorders, such as dyslipidemia and insulin resistance has risen worldwide in parallel with the risk of developing cardiovascular diseases, and type 2 diabetes[1]. With the growing impact of obesity on metabolic markers, dietary patterns have gained attention due to

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their potential health benefits. The Mediterranean diet emphasizes fiber-rich food through higher consumption of fruits, vegetables, legumes, and whole grains healthy fat from consumption of olive oil as the main fat, and low consumption of red meat, and dairy products[2,3]. The Mediterranean diet is rich in bioactive compounds such as antioxidants, and healthy fats, particularly polyunsaturated fatty acids (PUFAs) and monounsaturated fatty acids (MUFAs), and these bioactive compounds work synergistically to produce protective effects against metabolic disorders[4]. Several studies have investigated the effectiveness of the Mediterranean diet in improving insulin resistance, and lipid profiles[5,6]. Additionally, the Mediterranean diet has been associated with increased longevity[7] and protection against cardiovascular and neurodegenerative diseases, as well as type 2 diabetes[8].

Waist-hip ratio (WHR) is an indicator of central obesity and is associated with visceral fat accumulation[9,10]. Conflicting results have shown the beneficial effect of the Mediterranean diet on central obesity and fat mass[11]. Several studies suggest that the Mediterranean diet pattern significantly reduces waist circumference, improves WHR, and highlights its efficiency in lowering central obesity[12]. Additionally, it reduces weight gain and maintains weight loss[13]. On the other hand, several studies generally recognized the Mediterranean diet as a high-fat diet and are not recommended for overweight individuals[11].

There is conflicting evidence regarding the health benefits of the Mediterranean diet in reducing central obesity-related metabolic markers. Therefore, this study aims to explore the relationship between adherence to the Mediterranean diet and central obesity as well as related metabolic disorders.

METHODS

Study design and participation: A cross-sectional study was conducted from October 2020 to October 2021. The study included 480 participants between (18 - 65) years who attended nutrition and dietetics clinics in Amman. The study included participants who were diagnosed with metabolic disorders and willing to complete the assessment of the study. While, participants with severe chronic illnesses, pregnant and lactating women, those taking lipid-lowering and glucose-lowering medication or herbs, and those following a diet for medical reasons were excluded from the study. At enrolment, the participants were asked to report their sociodemographic data such as age, sex, education level, and smoking history.

Ethical considerations: The study protocol was reviewed and approved by the Institutional Review Board at Jerash University under the ethical consideration code ((1-12-2023/2024). All study protocols adhered to the principles of the Declaration of Helsinki. Informed consent was obtained from participants before enrollment.

Anthropometric measurement: The participant's weight was measured with light clothing and barefoot using bioelectrical impedance with Tanita body composition analyzer SC-330, the participant's weight was measured in kilograms to the closest (0.1 Kg). Height was measured using (seca 213 portable height measure); the mean of the two height measurements was taken to the nearest millimeter. Body mass index (BMI) was calculated based on weight divided by the height-squared meters[14]. Waist circumference was measured by non-elastic tape in the narrowest part between halfway of the lower ribs and the head of the iliac crest[15]. Hip circumference is measured at the widest part of the buttocks.

Biochemical tests: Metabolic parameters including serum triglycerides, High-density lipoproteins- cholesterol (HDL cholesterol), Low-density lipoproteins – cholesterol (LDL- cholesterol), LDL cholesterol, total cholesterol, Glycated hemoglobin (HbA1c), and fasting plasma glucose (FBS), were assessed using a commercial standard enzymatic kit[16].

The Mediterranean Diet Adherence Screener: The Mediterranean Diet Adherence was assessed based on the Mediterranean Diet Adherence Screener -14 (MEDAS-14)[5]. The screening tool includes fourteen food categories: consumed olive oil as the main source of fat and consumed at least 4 tablespoons daily, at least 2 servings of vegetables daily (one serving equals 200 grams or 7 ounces), at least 3 servings of fruits daily (one serving equals 200 grams or 7 ounces), at least 3 servings of nuts or seeds weekly, at least 3 servings of fish or seafood weekly (one serving equals 100-150 grams or 3.5-5 ounces), at least 3 servings of legumes each week (one serving equals 150 grams or 5.3 ounces), less than 2 servings of red meat or processed meat each week (one serving equals 100-150 grams or 3.5-5 ounces), and at least 3 serving of white meat chicken, turkey, or rabbit weekly (one serving is about 100-150 grams or 3.5-5 ounces). Additionally, limit sugary drink consumption to no more than one per day, restrict sweets intake to fewer than 2 servings per week, ensure 2 or more servings of homemade sauce per week, and consume 1 tablespoon or less of butter, margarine, or cream per day (one serving is about 12 grams or 0.4 ounces). Each question is scored as (1) for a (yes) response and (0) for a (no) response. The total score ranges from 0 to 14 and is classified into three levels: scores ≥10 reflect optimal adherence to the Mediterranean Diet, 7–9 indicate average adherence, and (0-6) indicate low adherence.

Statistical analysis: Data analysis was performed using SPSS software (SPSS Inc. Released 2008. SPSS Statistics for Windows, Version 17.0. Chicago: SPSS Inc). The normality of the continuous variable was checked using the Shapiro-Wilk test. Mean and standard deviation were used for continuous variables. Frequency and percentage were used for categorical variables. Pearson correlation was used to assess the linear re-

lationship between normally distributed variables. Additionally, multiple linear regression analysis was used to determine the association between the Mediterranean diet score and the metabolic parameters. The dependent variable included triglyceride levels, total cholesterol, HbA1c, HDL cholesterol, and waist-hip ratio. The independent variable is the Mediterranean diet food pattern represented by the Mediterranean diet adherence score. Beta coefficients (B) were calculated to estimate the direction and magnitude of changes of dependent variables for each unit increase in the Mediterranean diet adherence score. The stepwise entry method was used with a probability of F entry set at 0.05 to ensure that only variables that contribute significantly to the model ($p < 0.05$) were included in the final analysis. P-*value* was determined using the Chi-square test for categorical values and one-way ANOVA for continuous variables. A p-value < 0.05 was considered statistically significant. All p-values were reported, with those below 0.001 indicated as $p < 0.001$.

RESULTS

Table 1. Shows the socio-demographic and anthropometric characteristics of participants. There are significant differences between groups in terms of gender, the average adherence group had a higher proportion of females (54.9%) compared to a higher proportion of males (68.4%) in the optimal adherence group. Additionally, 43.2% of the optimal adherence group is among the age group of (36-45) years compared to 36.7% in the poor adherence group. Moreover, there were no significant differences between groups concerning education level and smoking. The average adherence and optimal adherence participants were more likely to be overweight on average (29.2 ± 4) and (28.4 ± 4.1) respectively. In addition, there were no significant differences in waist-hip ratio. However, the participants were more likely to have an increased waist-hip ratio.

Table 2. Presents Comparison of the distribution of Mediterranean diet food items among participants' group. MEDAS-14 was used to measure the degree of participants' adherence Mediterranean diet; however, the results of 12 components were obtained from participants. There were significant differences were observed for using olive oil as the main cooking fat among poor, average, and optimal adherence groups: 60.2%, 88.3%, and 84.2%, respectively ($p = 0.000$). There is a marked difference in the consumption of olive oil between the poor adherence group (39.1%) and the optimal adherence group (91.6%) ($p = 0.000$). In addition, the high adherence group showed a significant increase in vegetable intake (95.8% vs. 40.6% in the poor adherence group, $p = 0.000$) and higher fruit consumption (95.8% vs. 71.1% and 67.7% in poor and average adherence groups, $p = 0.000$). Consuming less than one serving of red meat is significantly higher among the optimal adherence group (96.8%) compared to (32.8%) in the poor adherence group ($p = 0.00$). Optimal adherence is linked with consuming butter, margarine, or cream less than one serving/day (73.7%) versus (37.5%) in the poor adherence group ($p = 0.01$). Moreover, lower consumption of sweet or carbonated beverages in the optimal adherence group was observed compared to the poor adherence group (88.4%, 21.1%, $p = 0.000$) respectively. Additionally, legume consumption was significantly higher among the optimal adherence group (75.8%, $p = 0.000$). The optimal adherence group tends to consume more than three servings of fish or shellfish weekly (63.2%) compared to (23.4%) in the poor adherence group ($p = 0.000$). Moreover, consumption of pastries, sweets, and candies less than three times per week is significantly higher in the optimal adherence group (88.4%, $p = 0.000$). There is no significant difference among groups regarding the consumption of chicken, turkey, or rabbit ($p = 0.201$), and nuts consumption ($p = 0.093$).

In Table 3. The results of the Pearson correlation analysis between the Mediterranean dietary score and metabolic parameters revealed a significant negative correlation between the Mediterranean diet score and triglyceride levels ($r = -0.689$, $p < 0.001$), cholesterol ($r = -0.613$, $p < 0.001$), cholesterol/HDL ratio ($r = - 0.531$, $p < 0.001$), triglyceride/HDL ratio ($r = - 0.555$, $p < 0.001$), HbA1c ($r = - 0.63$, $p < 0.001$), fasting blood sugar ($r = - 0.111$, $p < 0.05$), waist circumference ($r = - 0.103$, $p < 0.05$), and waist-hip ratio ($r = - 0.225$, $p < 0.001$). On the other hand, HDL-cholesterol is significantly positively associated with the Mediterranean diet score ($r = 0.746$, $p < 0.001$). the results indicate that higher adherence to the Mediterranean diet pattern is associated with lowered triglyceride levels, cholesterol, cholesterol/HDL ratio, triglyceride/HDL ratio, HbA1c, fasting blood sugar, waist circumference, and waist-hip ratio, and increased HDL cholesterol levels.

As shown in Table 4, the results of multiple linear regression indicate that higher adherence to the Mediterranean Diet is significantly and inversely associated with triglycerides ($B = - 0.244$, $p < 0.001$), total cholesterol ($B = - 0.180$, $p < 0.001$), HbA1c ($B = - 0.031$, $p < 0.001$), and waist-hip ratio ($B = - 0.065$, $p < 0.001$). Additionally, higher adherence to the Mediterranean Diet is significantly and positively associated with HDL cholesterol increases ($B = 0.512$, $p < 0.001$).

In summary, the multiple linear regression analysis results confirm that higher adherence to the Mediterranean Diet is significantly and inversely associated with improved lipid and glycemic profiles. Specifically, for each unit increase in the Mediterranean diet score, triglyceride levels are predicted to decrease by 0.244 units, total cholesterol decrease by 0.180 units, HbA1c levels drop by 0.031 units, and waist-hip ratio drop by 0.065 units. Additionally, HDL cholesterol increases by 0.512 units with each unit increasing adherence to the Mediterranean Diet.

Table 1. Socio-demographic and anthropometric characteristics among Mediterranean diet score group

Variables	Poor adherence score ≤ 6 N= 128 (26.7%)	Average adherence score (7-9) N= 257 (53.5%)	Optimal adherence score ≥ 10 N= 95 (19.8%)	p-*value*
Sex				0.000**
Male	59 (46.4%)	116 (45.1%)	65 (68.4%)	
Female	69 (53.9%)	141 (54.9%)	30 (31.6%)	
Age (years)				0.000**
18-25	3 (2.3%)	25 (9.7%)	8 (8.4%)	
26-35	31 (24.2%)	63 (24.5%)	34 (35.8%)	
36-45	47 (36.7%)	72 (28%)	41 (43.2%)	
>45	47 (36.7%)	97 (37.7%)	12 (12.6%)	
Education level				0.000**
≤ higher school	63 (49.2%)	94 (36.6%)	51 (53.7%)	
Bachelor degrees	49 (38.3%)	151 (58.8%)	40 (42.1%)	
Higher education	16 (12.5%)	12 (4.7%)	4 (4.2%)	
Smoking				0.003*
Yes	66 (51.6%)	134 (52.1%)	68 (71.6%)	
No	62 (48.4%)	123 (47.9%)	27 (28.4%)	
BMI	**30.1 ± 4**	**29.2 ± 4**	**28.4 ± 4.1**	0.01*
18.5- 24.9	12 (9.4%)	35 (13.6%)	24 (25.3%)	
25- 29.9	51 (39.8%)	123 (47.9%)	41 (43.2%)	
30- 34.9	54 (42.2%)	83 (32.3%)	20 (21.1%)	
≥ 35	11 (8.6%)	16 (6.2%)	10 (10.5%)	
Weight (kg)	88.3 ± 15.2	84.9 ± 11.8	83.3 ± 13.2	0.012*
Height (cm)	171.1 ± 10.2	170.6 ± 8.9	171.4 ± 10.3	0.752
Waist circumference (cm)	78.8 ± 15.6	73.7 ± 12.4	77.3 ± 10.2	0.000**
Hip circumference (cm)	73.6 ± 13.6	775.5 ± 12.5	78.6 ± 14.7	0.021*
Waist hip ratio	1.09 ± 0.2	0.99 ± 0.2	1.02 ± 0.2	0.000**

BMI: Body mass index; kg: Kilogram; cm: Centimeter.
Data are expressed as mean ± SD for continuous data, and percentage for categorical data.
* Significant at< 0.05 level, ** Significant at < 0.001 level.

Table 2. Comparison of the distribution of Mediterranean diet food items among participants' group

Mediterranean diet items	Mediterranean Diet Index						*p* – value
	Poor adherence score ≤ 6 N= 128 (26.7%)		Average adherence score (7-9) N= 257 (53.5%)		Optimal adherence score ≥ 10 N= 95 (19.8%)		
	Yes	No	Yes	No	Yes	No	
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	
Use olive oil as the primary cooking fat	77 (60.2%)	51 (39.8%)	227 (88.3%)	30 (11.7%)	80 (84.2%)	15 (15.8%)	0.000**
Consume at least 4 tablespoons of olive oil per day	50 (39.1%)	78 (60.9%)	183 (71.2%)	74 (28.8%)	87 (91.6%)	8(8.4%)	0.000**
consume at least 2 servings of vegetables per day	52 (40.6%)	76 (59.4%)	205 (79.8%)	52 (20.2%)	91 (95.8%)	4 (4.2%)	0.000**
consume at least 3 servings of fruits per day	91 (71.1%)	37 (28.9%)	174 (67.7%)	83 (32.3%)	91 (95.8%)	4 (4.2%)	0.000**
consume at least one serving of red meat per day	42 (32.8%)	86 (67.2%)	166 (46.6%)	91 (35.4%)	92 (96.8%)	3 (3.2%)	0.000**
consumption of butter, margarine, or cream should be limited to 1 serving per day	48 (37.5%)	80 (62.5%)	151 (58.8%)	106 (41.2%)	70 (73.7%)	25 (26.3%)	0.011*
Limit sweet or carbonated beverages to less than 1 serving per day	27 (21.1%)	101 (78.9%)	105 (40.9%)	152 (59.1%)	84 (88.4%)	11 (11.6%)	0.000**
Consume at least 3 servings of legume per week	70 (54.7%)	58 (45.3%)	182 (70.8%)	75 (29.2%)	72 (75.8%)	23 (24.2%)	0.000**
Consume at least 3 servings of fish or shellfish per week	30 (23.4%)	98 (76.6%)	158 (61.5%)	99 (38.5%)	60 (63.2%)	35 (36.8%)	0.000**
Limit pastries, sweets, and candies to less than 3 times per week	63 (49.2%)	65 (50.8%)	153 (59.5%)	104 (40.5%)	84 (88.4)	11 (11.6%)	0.000**
Consume at least 3 servings of nuts per week	64 (50%)	64 (50%)	150 (58.4%)	107 (41.6%)	61 (64.2%)	34 (35.8%)	0.091
Consume at least 3 servings of chicken, turkey, or rabbit per week	111 (86.7%)	17 (13.3%)	218 (84.8%)	39 (15.2%)	74 (77.9%)	21 (22.1%)	0.201

* Significant at< 0.05 level, ** Significant at < 0.001 level.

DISCUSSION

The current study found significant variation in the consumption of Mediterranean diet components among groups. The optimal Mediterranean diet consumption is associated with a higher consumption of olive oil, fruits, vegetables, legumes, and seafood, and a lower intake of red meat, refined sugar, sweets, and candies. The findings of the current study support the findings of the previous studies[17-20]. Bioactive compounds such as polyphenols, MUFAs, and PUFAs in the Mediterranean diet are associated with improved lipid profile, improved insulin sensitivity, and reduced oxidative stress[21]. Mediterranean diet also showed a significant consumption of fibers from fruit and vegetables that are linked to enhanced gut microbiota metabolites, reduced risk of chronic disease, and increased life expectancy[22].

Table 3. Pearson correlation between Mediterranean dietary score and metabolic parameters

Variables	Mean ± SD	Pearson correlation	p- value
Waist circumference	75.8 ± 13.1	-0.103	0.012*
Fasting blood sugar	112.5 ± 64.3	-0.111	0.007*
HDL- cholesterol	54.1 ± 21.6	0.746	0.000**
Cholesterol	268 ± 153.4	-0.613	0.000**
Cholesterol/HDL ratio	7.5 ± 8.8	-0.531	0.000**
LDL- Cholesterol	180.9 ± 50.5	-0.054	0.122
Triglyceride	222 ± 122.6	-0.689	0.000**
HbA1c	6.4 ± 2.3	-0.63	0.000**
Waist hip ratio	1.03 ± 0.2	- 0.225	0.000**
Triglyceride/HDL ratio	8.8 ± 15.6	-0.555	0.000**

HDL: High-density lipoproteins; LDL: Low-density lipoproteins; HbA1c: Glycated hemoglobin.
* Significant at< 0.05 level, ** Significant at < 0.001 level.

Table 4. Association between the Mediterranean diet score and the metabolic parameters

Parameters	Standardized Coefficients Beta	R Square	F	p-value
Triglyceride	- 0.244	0.641	172.240	0.000*
Cholesterol	-0.180			
HDL- cholesterol	0.512			
HbA1c	- 0.031			
Waist hip ratio	- 0.065			

HDL: High-density lipoproteins; HbA1c: Glycated hemoglobin.
* Significant at < 0.001 level.

The results of the study found that the Mediterranean diet is inversely associated with BMI, waist circumference, and waist-hip ratio. Increases in the waist-to-hip ratio are associated with abdominal obesity and metabolic disorders[23]. Several studies have reported a positive impact of the Mediterranean diet on reducing central obesity, with or without energy restriction[24]. Additionally, it is not associated with weight gain without energy restriction[25], while the Mediterranean diet along with energy restriction and regular physical activity leads to greater weight loss[26]. Research indicates that high fiber and moderate MUFAs diet in the Mediterranean diet is linked to reduced abdominal obesity and improved metabolic health[27] by enhancing gut microbiome metabolite from the production of short-chain fatty acids (SCFAs)[28]. In addition, the higher consumption of MUFAs and lower consumption of saturated fats in the Mediterranean diet is linked to the composition of subcutaneous fat from MUFAs and PUFAs, which leads to lower waist-hip ratio, reduced central obesity, and visceral fat. A Mediterranean diet rich in virgin olive oil, without calorie restriction, can reduce overall body fat accumulation without affecting body weight[29]. Strict adherence to this diet pattern can help control obesity and waist circumference[30]. Studies show that the Mediterranean diet with caloric restriction is effective in reducing body weight, fat mass, and visceral fat[31].

The study found an inverse relationship between the Mediterranean diet score and the level of triglyceride, total cholesterol, LDL-cholesterol, cholesterol/HDL ratio, triglyceride/HDL ratio, HbA1c, fasting blood sugar, waist circumference, and waist-hip ratio. The results of our study are consistent with the findings of several studies[2,32,33]. The results of prospective randomized clinical trial studies emphasize the benefits of consuming healthy fats from virgin olive oil and nuts, as well as fiber-rich foods from whole grains, legumes, vegetables, and fruits for cardiovascular health[5]. In addition, the Mediterranean diet's beneficial effects are attributed to the presence of polyphenols, potassium, and vitamins in fruits, vegetables, and whole grains[34]. The Mediterranean diet's components work synergistically; the fiber in the diet plays a key role in reducing the absorption of cholesterol from food. In addition, phenolic compounds from olive oil have anti-inflammatory and antioxidant effects[27,35] and improve the immune system by reducing the production of IL-12, IL-1B, and TNF-α[36]. The Mediterranean diet incorporates PUFAs from nuts, seeds, and fatty fish such as salmon, which contribute to cardiometabolic health[37]. Higher consumption of omega-3 PUFAs has been associated with lowering the risk of developing atherosclerosis among high-risk populations by lowering triglyceride, and LDL cholesterol, and increasing HDL cholesterol levels[16,38,39].

The study found that the Mediterranean diet is inversely associated with HbA1C and blood sugar levels. The diet's high intake of olive oil, nuts, legumes, whole grains, and fruits, along with low meat consumption, helps prevent type 2 diabetes and gestational diabetes and treat insulin resistance[40]. A higher intake of omega-3 PUFAs from fatty fish, nuts, and MUFAs from olive oil and a lower intake of trans and saturated fatty acids have been shown to improve insulin sensitivity and glycemic control[41], while also benefiting lipid profile and insulin resistance in women with polycystic ovarian syndrome[42].

CONCLUSION

In conclusion, the results of the study indicate the beneficial effects of adherence to the Mediterranean diet on weight

control and metabolic disorders improvement. Therefore, the Mediterranean diet should be considered a key aspect of public health nutritional strategies to control the increasing prevalence of obesity and metabolic disorders. Further clinical trials are necessary to examine the long-term effects of the Mediterranean diet on diverse populations to enhance evidence-based dietary recommendations.

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