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Evaluation of the determinants of adherence to the Mediterranean diet in an adult population of Khouribga province in Morocco

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RESUMEN

Los efectos beneficiosos de la dieta mediterránea (DM) sobre la salud han disminuido en los últimos años en los países ribereños del mar Mediterráneo. Objetivo: Estudiar los determinantes de la adherencia a la DM en una población adulta de la provincia de Khouribga en Marruecos. Material y métodos: Se realizó un estudio transversal para recopilar datos sobre la dieta, el estilo de vida, las características sociodemográficas y bioquímicas de 400 adultos, y se evaluó la puntuación de adherencia a la DM (DDM) utilizando la frecuencia de consumo de ocho grupos de alimentos (verduras, legumbres, frutas, cereales o patatas, pescado, carne roja, productos lácteos y aceite de oliva). Resultados: la adherencia a la DM fue baja con independencia de la zona de residencia (MDS media=3,91; SD=0,07), con un 61,7% de individuos no adherentes en las áreas urbanas y un 73,5% entre las personas obesas; la mayor adherencia a la DM se encontró en el grupo de edad de 35 a 50 años. En cuanto al género, las mujeres consumen más carne (Me=1,13) que los hombres y ellos consumen más frutas (Me=1,33), siendo las diferencias significativas. En los hombres, la baja adherencia a la DM se caracteriza por menores frecuencias de consumo de legumbres (29,2%) y pescado (31,6%) respecto a los de alta adherencia, que consumen un 70,8% y 68,4% de estos alimentos, respectivamente. En las mujeres, los porcentajes de frecuencia de consumo de los grupos de alimentos que más contribuyen a la adherencia son las frutas (60,3%) y las legumbres (55,3%). Conclusiones: Los datos muestran que en la población estudiada de la provincia de Khouribga, la adherencia a la DM es baja y está determinada por los hábitos alimentarios y los factores sociodemográficos. Estos resultados también sugieren que promover un mayor consumo de frutas, verduras, cereales, legumbres, pescado y aceite de oliva y disminuir el consumo de carne y productos lácteos, de acuerdo con la pirámide mediterránea, podría contribuir a reducir los riesgos de enfermedades crónicas y mejorar la calidad de vida de la población de la región estudiada.

Palabras clave:

Dieta mediterránea
Índice MDS
Adherencia a la DM
Factores sociodemográficos
Khouribga (Marruecos)

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ABSTRACT

The beneficial effects of the Mediterranean diet (MD) on health have declined in recent years in countries bordering the Mediterranean Sea. Objective. To study the determinants of adherence to MD in an adult population of the Khouribga province in Morocco. Material and methods: A cross-sectional study was conducted to collect data on diet, lifestyle, sociodemographic and biochemical characteristics from 400 adults and MD adherence score (MDS) was assessed using the frequency of consumption of eight food groups (vegetables and potatoes, legumes, fruits, cereals and their derivatives, fish, red meat, dairy products and olive oil). Results: Adherence to MD was low regardless of the area of residence (mean MDS=3.91; SD=0.07) with 61.7% from urban areas and 73.5% among obese people not adhering to MD. However, the highest adherence to MD was found in the 35-50 age group. Regarding gender, women consume more meat (Me=1.13) while men consume more fruits (Me=1.33); these differences were significant. In men, low adherence to MD is characterized by lower frequencies of consumption of legumes (29.2%) and fish (31.6%) compared to those with high adherence to MD (70.8% and 68.4%, respectively). In women, the percentages of frequency of consumption of the food groups that contribute most to adherence are those of fruits (60.3%) and legumes (55.3%). Conclusions: The data show that in the studied population of Khouribga province, adherence to MD was low and determined by dietary habits and sociodemographic factors. These results also suggest that promoting the consumption of more fruits, vegetables, cereals, legumes, fish and olive oil and less meat and dairy products in accordance with the Mediterranean pyramid, could contribute to reducing the risks of chronic diseases and improving the quality of life of the population in the study region.

Keywords:

Mediterranean diet
MDS score
Adherence to MD
Sociodemographic factors
Khouribga (Morocco)

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Introduction

The Mediterranean diet (MD) is a traditional diet of countries bordering the Mediterranean Sea, including Spain, Italy and Greece on the northern shore, some countries of the Middle East region in the East and countries of North Africa in the southern shore including Morocco. The diet of these countries is of the Mediterranean type. This diet has been recognized by international organizations as a healthy diet (WHO, 2018) and considered a sustainable dietary model (FAO, 2012) which is why it has been included in the World Heritage List (UNESCO, 2010). The overall quality of the diet has an important role in the development of cardiovascular diseases and chronic diseases. Among these high-quality diets, MD has shown positive effects in preventing the incidence of these diseases and has been associated with reduced mortality. Indeed, a meta-analysis of several cohort studies indicated that the adoption of MD reduced the risk of all-cause mortality (Sofi et al., 2008).

Several studies including the PREDIMED study have also reported this positive effect of MD in the prevention of diabetes (Damigou et al., 2023; Rivas-García et al., 2024), blood sugar control in addition to body weight management, a reduction in obesity and hypertension (Abellán Alemán et al., 2016; El Kinany et al., 2018) as well as a reduction in the risk of cardiovascular and metabolic diseases (Ouhaibi-Djellouliet al., 2020; Alnabulsi et al., 2024) and type 2 diabetes (Restivo, 2023; Zheng et al., 2024). MD has also been reported to have a role in preserving cognitive functions and reducing the risk of neurodegenerative diseases (Armeli et al., 2021). In addition, a reduction in the risk of certain cancers and a 28% decrease in cancer mortality has also been associated with adherence to the Mediterranean lifestyle (Restivo, 2023; Saddoud et al., 2023;). However, changes in lifestyle and dietary habits are observed in several countries of the Mediterranean basin has led to an abandonment of this diet, as the case in some southern Mediterranean countries (Egypt, Jordan, Tunisia, Algeria and Libya) where an increasing move away of populations from this traditional diet has been reported associated with an increase in animal sources and vegetable oils in their diet (Rguibi and Belahsen, 2006). Low adherence to the MD has also been observed among women of childbearing age in United Arab Emirates (Naja et al., 2022) and in Saudi Arabia where only 21% of the population adheres to this diet (Alnabulsi et al., 2024). Similarly, an abandonment of traditional MD has been noted in North Africa among populations in Algeria (Ouhaibi-Djellouliet al., 2020) and Morocco (Mziwira et al., 2015).

Furthermore, in countries of this region, adherence to MD varies by region, ranging from moderate adherence to low adherence in others. Thus, a deviation from MD has been previously reported in Morocco in the provinces of El Jadida (Mziwira et al., 2015), Casablanca (Mohtadi et al., 2020) and a similar decline in adherence to MD has also been recently reported in Nador and Oujda (Benyaich et al., 2022) and in El Jadida (Moustakim et al., 2022; Mziwira et al., 2024).This shift is further influenced in Morocco by socioeconomic factors, place of residence as well as by the distance from the Mediterranean Sea (El Rhazi et al., 2012; El Kinany et al., 2018; Barakat et al., 2022; Elfane et al., 2024; Mziwira et al., 2024).

Although emphasis has been placed on healthy fats from olive oil and nuts among the components of MD, the protective effects of this diet have been associated with its quality, namely its richness in antioxidants and anti-inflammatory nutrients (Kalili et al., 2022; Aboukhalaf et al., 2023; Restivo, 2023; Essaih et al., 2024).In this study, the objective was to characterize the diet and to study the nutritional status and determinants of adherence to MD in an adult population located far from the Mediterranean, in the province of Khouribga in Morocco.

Material and methods

Description of the study sample

The province of Khouribga was created on July 10, 1967, it belongs to the large Region of Beni Mellal-Khénifra, located 120 km southeast of the economic capital of Morocco (Casablanca). It is a mining city considered the most important phosphate production area in the kingdom. It includes five urban and 26 rural communes with a high urbanization rate of 69.7%. The number of inhabitants is 342,125 (HCP, 2017) with an area of 4,250 km² and a density of 81 inhabitants/km² (Figure 1).This study was conducted in

2019 on a randomly selected sample of 400 individuals (149 men and 245 women), living in the province of Khouribga in Morocco and aged 18-65 years. The average age was 39.27 (0.84 SD) in women, and 41.91(1.16 SD) in men. The recorded level of education was primary in 24.7%, secondary in 36.5%, higher level in 6.2% and none in 31.3% of this population. The active population was distributed as follows: 49.3% employees, 38.5% self-employed and 12.2% others. However, the unemployment rate was 6.7% in this province population compared to 9.7% at national level (HCP., 2017) Pregnant women, paralyzed patients and people with a history of diseases were excluded from the survey.

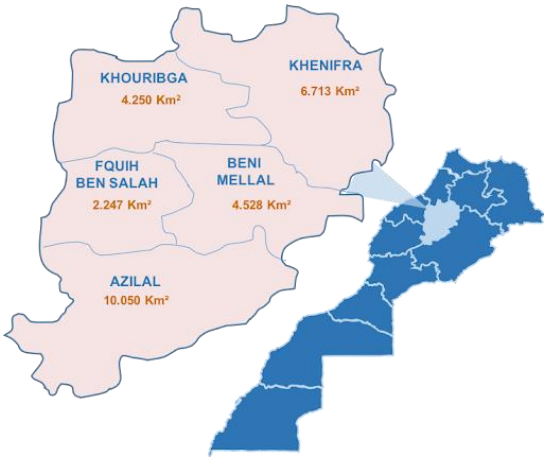

Figure1. Geographic map of the Beni-Mellal-Khenifra region and location of the Khouribga province.

Anthropometric measurements

Weight was measured using a scale ± 100g, height by a tape measure ± 1mm, and body mass index (BMI) was calculated by dividing weight (kg) by the square of height (m²). The World Health Organization (WHO) criteria was used to define normal weight as 18≤BMI and obese when are BMI≥ to 30.BMI ranges of 18.5 to 25 kg.m^{-2} correspond to normal weight, between 25 and 30 kg. m^{-2} to overweight, and BMI>30 kg. m^{-2} define obesity

Metabolic parameters

After an overnight fast, a volume of 3 ml of blood was collected in EDTA tubes, and serum was separated in an Eppendorfs after decantation and used for serum analyses and blood glucose (Gly) (Normal: Gly=70-120mg/dL), triglycerides (TG) (Normal: 60-150 mg/dL), total cholesterol (TChol) (Normal: 150-250mg/dL) and uric acid (Uac) were measured. Systolic (SBP) and diastolic blood pressure (DBP) were measured after a 5-10 minutes rest, using a self-measurement device (OMRON). Hypertension is defined as SBP > 140 mmHg and DBP > 90 mmHg, or one of the two is raised.

Adherence to Mediterranean diet

Adherence to MD was evaluated using Mediterranean Diet Score (MDS), a scale that was created as a composite of foods considered characteristic of MD and using a food frequency questionnaire (FFQ) as the most adopted method to estimate an individual's adherence to this healthy dietary pattern (Trichopoulou et al., 2003). The score MDS is calculated for each of the 8 food groups components by assigning a value of 0 or 1 to each of them. For the beneficial components (fruits, vegetables, olive oil, whole grains, legumes, fish, and nuts), a value of 1 was assigned to those whose consumption was equal to or greater than the median, while a value of 0 was assigned to those whose consumption was below the median. For the harmful components (dairy, red meat, and processed foods), a value of 1 was assigned to those whose consumption was below the median and 0 for those whose consumption was equal to or greater than the median. The Mediterranean diet score ranges from 0 (the lowest adherence to the traditional Mediterranean diet) to 8, the highest adherence. This index is then used to categorize individuals into two groups according to their adherence score to MD. When this MDS is between 0 and 4 points, individuals were considered to be of low adherence to MD and those with a score ranging from 5 to 8 points were included in the category with high adherence to MD (Trichopoulou et al., 2003; Benyaich et al., 2022; Moustakim, 2022).

Statistical analyses

Summary statistics are used to describe the population using SPSS version 23 software. Continuous variables (Age (yrs), BMI (kg.m^{-2}), Nap

(min), TV time (min), Blood systolic (SBP) and diastolic pressure (DBP) (mmHG), Heart rate (bpm), Glycemia (mg/dL), Triglyceridemia (mg/dL), Total Cholesterol (mg/dL) and Uric acid (mg/dL)), are presented as mean and standard deviation (SD), while categorical variables are reported in terms of frequency and proportions. To compare differences in means, we used the Student t-test, while the Chi-square test (X^2) was used to assess differences in proportions. In addition, the Mann-Whitney test was applied for comparisons between groups. In all statistical tests, a P-value less than 0.05 was considered statistically significant.

PASSAGE software was also used to assess the effect of the distance on adherence to the Mediterranean diet; this program allows data analysis by taking into account the spatial autocorrelation. In this study, this approach is used to examine how geographical distance (longitude-latitude) influences dietary habits within the study population, using spatial autocorrelation methods between different MDS and distance from the Mediterranean Sea. The results obtained by this analysis are integrated to better understand the geographical factors affecting adherence to the Mediterranean diet in the study sample.

Ethical aspects

Before the study, the protocol was authorized by the health authorities of the province of Khouribga. Information on the study objectives and conduct as well as their voluntary participation to the research was given to the respondents and anonymity, self-determination and fair and equitable treatment were guaranteed. They also were asked to give their consent before their inclusion in the study.

Results

Table 1 describes the results of the different variables studied in the population of the province of Khouribga. The table shows that the averages of BMI, systolic blood pressure, heart rate, and monthly income are significantly different in both genders ($P<0.05$). However, no difference was observed for age, time spent in front of the TV, napping and the five abnormalities examined. No-parametric tests were used to compare the medians of food frequencies in both genders (Table 2). The results obtained show that men consume meat and fruit more frequently than women and the differences are highly significant ($P<0.05$). Indeed, the MDS is higher in men than in women. The data show that the overall mean of the MD adherence score (MDS) was 3.91 and was comparable for both urban (3.94) and rural (3.98) residential areas. However, this score was different according to gender with a higher mean in men (4.33) compared to women (3.71), with a highly significant difference ($P= 0.000$) (Table 2). The results obtained in the population of the province of Khouribga regarding adherence to MD, according to the sociodemographic characteristics, BMI categories, and activity level, are gathered in Table 3. As shown in the table, the majority of the study population does not adhere to the Mediterranean diet. The proportion of adherence varies according to gender since it corresponds to 68.6% of women compared to 51% of men who do not adhere to this diet. However, according to the residential environment, the data shows similar proportions of individuals who do not adhere or who have low adherence in both urban (61.7%) and rural (61%) environments. This suggests that the living environment (urban or rural) has no significant impact on adherence to the Mediterranean diet.

Among all age groups studied, the highest adherence to the MD was found in both, the 35-50 age group and >50 years (43% and 43.6%, respectively), but differences among age groups were not significant. The salaries were not entered as amounts in dirham but classified as low income when it is<3000dh, medium if between 3000 and 5000 and high if the income was >5000dh per month. The comparison of the three age groups by income showed significant differences ($P=0.01$), with the age group of 35 to 50 having the lowest percentage (29.5%) of people with low income compared to the other groups of 18 to 34.99 (37.9%) and >50 years (32.6%); the latter class has the highest rate (36.4%) for high incomes in comparison with the other age groups (data not shown).

Table 1. Comparisons of sociodemographic, anthropometric and metabolic characteristics of the study population in the province of Khouribga.

	Men (n=149)	Women (n=245)	Global	
		(Mean; SD)		P-value
Age (years)	148 (41.91; 1.16)	242 (39.27;0.84)	390 (40.27; 0.68)	NS
BMI (kg.m^{-2})	149 (24.91; 0.35)	244 (29.07; 0.39)	393 (27.46; 0.29)	0.000***
Nap (min)	145 (31.12; 3.69)	243 (39.27; 2.33)	388 (36.22; 2.01)	NS
TV (min)	144 (194.74; 12.32)	243 (197.85; 8.73)	387 (196.69; 7.13)	NS
SBP (mmHG)	142 (13.29; 0.15)	240 (12.64; 0.11)	382 (12.88; 0.09)	0.000***
DBP (mmHG)	142 (8.47; 0.09)	240 (8.38; 0.07)	382 (8.40; 0.05)	NS
Heart rate (bat/min)	142 (78.83; 0.95)	239 (81.99; 0.78)	381 (80.81; 0.61)	0.01*
Gly (mg/dL)	107 (117.00; 4.80)	220 (108.00; 3.00)	327 (111.00; 2.70)	NS
TG (mg/dL)	104 (135.00; 8.00)	206 (126.00; 5.00)	310 (129.00; 2.80)	NS
TChol (mg/dL)	94 (165.00; 5.00)	199 (171.00; 3.00)	293 (169.00; 4.20)	NS
UAc (mg/dL)	91 (5.45; 0.16)	184 (5.16; 0.12)	275 (5.25; 0.09)	NS
Monthly income				
Low	42 (29.0%)	92 (38.0%)	134 (34.6%)	
Medium	36 (24.8%)	85 (35.1%)	121 (31.3%)	0.001**
High	67 (46.2%)	65 (26.9%)	132 (34.1%)	
Blood pressure				
Normotensive	91 (64.1%)	172 (71.7%)	263 (68.8%)	NS
Hypertensive	51 (35.9%)	68 (28.3%)	119 (31.2%)	

BMI: Body Mass Index; TV: Television; SBP: Systolic Blood pressure; DBP: Diastolic Blood pressure; Gly: Glycemia; TG: triacylglycerol (triglyceridemia); TChol: Total Cholesterol; UAc: Uric acid; Hypertensive: SBP > 140mmHg. and/or DBP > 90 mmHg. SD: Standard Deviation; *: 0.05<P<0.01; **: 0.01<P<0.001; ***: P<0.001. NS: Non-significant difference (t-test and X^2 test).

Table 2. Comparisons of Food frequency consumption and MDS of the study population in the province of Khouribga.

	Men	Women	Global	
FFC /Day	Median and Quartiles (25%-75%)			P-value
Meat	1.01 [0.67-1.32]	1.13 [0.77-1.54]	1.07 [2.78-4.37]	0.003 **
All cereals	3.72 [2.97-4.62]	3.74 [2.97-4.45]	3.74 [2.78-4.37]	NS
Vegetables	2.78 [1.81-3.50]	2.84 [1.68- 3.74]	2.80 [2.78-4.37]	NS
Dairy products	0.71 [0.41-1.02]	0.84 [0.42-1.41]	0.76 [2.78-4.37]	NS
Fish	0.14 [0.00-0.34]	0.12 [0.00-0.27]	0.12 [0.00-0.30]	NS
Legumes	0.17 [0.04-0.28]	0.14 [0.06-0.31]	0.15 [0.06-0.28]	NS
Olive oil	0.06 [0.03-0.14]	0.06 [0.03-0.14]	0.06 [0.03-0.14]	NS
Fruits and nuts	1.33 [0.72-2.25]	0.63 [0.36-1.01]	0.84 [0.42-1.40]	0.000 ***
MDS	4.32±0.12	3.71±0.09	3.91±0.07	0.000 ***

FFC: Food frequency consumption. MDS: Mediterranean diet score. **: 0.01<P<0.001; ***: P<0.001; NS: Non-significant difference (X^2 test).

The results in the Table 3 also show a significant difference in adherence to the MD according to BMI categories, with a majority of individuals in the obese category (73.5%) not adhering compared to only 26.5% of individuals in this class adhering to the Mediterranean diet. In addition, a large proportion of sedentary participants (69.5%) also had low adherence to this MD. Furthermore, a strong association was found between sedentary lifestyle and adherence to the MD. However, statistical analysis did not show any significant impact of time spent watching television on this adherence (Table 3). Statistical analyses using the Chi-square test (X^2) and the t-test were performed to better understand the associations between adherence to the MD and the various metabolic parameters (glycemia, cholesterolemia, triglycerides and uric acid), as well as hypertension and heart rate (Table 4). The results showed significant differences only regarding heart rate; specifically, the t-test revealed that the mean heart rate in individuals who adhere to the MD was lower (78.81 beats per minute) than those with

low adherence to this diet (82.10 beats per minute), this difference was statistically significant (P=0.008).

Table 3. Adherence to MD according to the sociodemographic characteristics, BMI categories, and activity level of the population under study.

	Low adherence to MD	High adherence to MD	P-value
Area of residency			
Urban (n=235)	145 (61.7%)	90 (38.3%)	NS
Rural (n=154)	94 (61.0%)	39 (40.0%)	
Gender			
Men (n=149)	76 (51.0%)	73 (49.0%)	0.000***
Women (245)	168 (68.6%)	77 (31.4%)	
Age categories			
18-34.99 yrs	102 (68.0%)	48 (32.0%)	
35-50 yrs	77 (57.0%)	58 (43.0%)	NS
>50 yrs	57 (56.4%)	44 (43.6%)	
Monthly income			
Low	86 (64.2%)	48 (35.8%)	
Medium	74 (61.1%)	47 (38.9%)	NS
High	79 (59.8%)	53 (40.2%)	
BMI categories			
Normal weight	78 (49.4%)	80 (50.6%)	
Overweight	84 (68.3%)	39 (31.7%)	0.000**
Obese	86 (73.5%)	31 (26.5%)	
Nap duration			
<30 min	133 (56. 1%)	104 (43.9%)	0.008**
>30 min	105 (69.5%)	46 (30.5%)	
Time in front of the TV			
<60 min	43 (56.6%)	33 (43.4%)	NS
>60 min	194 (62.4%)	117 (37.6%)	

MD: Mediterranean diet; BMI: Body Mass Index; TV: television; *: 0.05<P<0.01; **: 0.01<P<0.001; ***: P<0.001; NS: Non-significant difference (X^2 test).

Table 4. Association between adherence to MD (MDS) and metabolic parameters.

	Low adherence to MD	High adherence to MD	P-value
BP (mmHG)			
Normal BP	161 (61.2%)	102(38.8%)	NS
High SBP or DBP	72 (60.5%)	47 (39.5%)	
Heart rate (beats per minute)	82.10	78.81	0.008**
Gly			
Normal (<120mg/dL)	156 (63.2%)	91 (36.8%)	NS
Hyperglycemia (>120mg/dL)	43 (53.8%)	37 (46.2%)	
TChol			
Normal (<250mg/dL)	169 (61.0%)	108 (39.0%)	NS
High (>250mg/dL)	9 (56.2%)	7 (43.8%)	
TG			
Normal (<150mg/dL)	136 (61.0%)	87 (39.0%)	NS
Abnormal (>150mg/dL)	53 (60.9%)	34 (39.1%)	
Uric Acid			
Normal (<6 mg/dL)	111 (63.1%)	65(36.9%)	NS
High (>6 mg/dL)	58 (58.6%)	41(41.4%)	

MD: Mediterranean diet; BP: Blood pressure; Gly: Glycemia; TChol: Total Cholesterol; TG: Triglycerides; *: 0.05<P<0. 01; **: 0.01<P<0.001; ***: P<0.001; NS: Non-significant difference (t-test and X^2 test).

The assessment of dietary behaviors influencing adherence to the MD was studied (Table 5). The X^2 test was used to analyze this influence of the frequency of consumption of the eight food groups (cereals and derivatives, fruits and nuts, legumes, vegetables, fish, olive oil, dairy products, and meats) on the level of adherence to the MD in each gender. In men, the analyses revealed very highly significant differences for all food groups; the same significant differences were observed in women (Table 5). For beneficial foods, a less frequent consumption of cereals was observed in men who have a low adherence to the MD, with a proportion of 38.6% > the median, against 61.4% in those with a high adherence. For non-beneficial foods, such as dairy and meat, men with high adherence to the MD consumed these foods less, with 31.9% and 32.9%, respectively > the median, while those with low adherence to the MD consumed them more frequently, with 68.1% above the median for dairy and 67.1% above the median for meat consumption (Table 5). Similar trends were observed in women as elucidated through the consumption of the cereal food group for example. Indeed, the consumption of beneficial foods was less frequent in females with low adherence to the MD, with a proportion of 78, 9% below the median, than those with high adherence to this diet (21,1%), this difference is highly significant (P=0.000). Regarding non-beneficial foods, such as dairy products and meats, a more frequent consumption of these foods was present in women with low adherence to the MD, with 75.7% above the median for dairy products against 24.3% for women with high adherence to this diet. The same is true for meat consumption with highly significant differences. High consumption of dairy products and meats, classified as non-beneficial foods in this context, has been associated with various health risks, including cardiovascular diseases, hypercholesterolemia and obesity (Abellán Alemán et al., 2016; El Kinany et al., 2018; Alnabulsi et al., 2024).

Table 5. Daily frequency of food consumption by gender and level of adherence to MD.

FFC	Men		P-value	Women		P-value
	Adherence to MD			Adherence to MD		
	Low	High		Low	High	
Cereals						
<Median	49 (62.0%)	30 (38.0%)	0.004**	97 (78.9%)	26 (21.1%)	0.000***
≥ Median	27 (38.6%)	43 (61.4%)		71 (58.2%)	51 (41.8%)	
Fruits and nuts						
<Median	33 (80.5%)	9 (19.5%)	0.000***	137 (82.0%)	30 (18.0%)	0.000***
≥ Median	43 (40.2%)	64 (59.8%)		31 (39.7%)	47 (60.3%)	
Legumes						
<Median	57 (67.8%)	27 (32.2%)	0.000***	122 (85.9%)	20 (14.1%)	0.000***
≥ Median	19 (29.2%)	46 (70.8%)		46 (44.7%)	57 (55.3%)	
Vegetables						
<Median	54 (66.7%)	27 (33.3%)	0.000***	108 (83.1%)	22 (16.9%)	0.000***
≥ Median	22(32.4%)	46 (67.7%)		60 (52.2%)	55 (47.8%)	
Fish						
<Median	51 (72.9%)	19 (27.1%)	0.000***	108 (83.7%)	21 (16. 3%)	0.000***
≥ Median	25 (31.6%)	54 (68.4%)		60 (51.7%)	56(48.3%)	
Olive oil MUFA						
<Median	34 (73.9%)	12 (26.1%)	0.000**	62 (82.7%)	13 (17.3%)	0.002**
≥ Median	42 (40.8%)	61 (59.2%)		106 (62.4%)	64 (37.6%)	
Dairy product						
<Median	29 (36.2%)	51 (63.8%)	0.000***	56 (57.7%)	41 (42.3%)	0.003**
≥ Median	47 (68.1%)	22 (31.9%)		112(75.7%)	36 (24.3%)	
Meat						
<Median	25 (34.2%)	48 (65.8%)	0.000***	61 (56.5%)	47 (43.5%)	0.000***
≥ Median	51 (67.1%)	25 (32.9%)		107 (78.1%)	30 (21.9%)	

FFC: Food frequency consumption; MD: Mediterranean diet; MUFA: Monounsaturated fatty acids;*: 0.05<P<0.01; **: 0.01<P<0.001; ***: P<0.001. NS: Non-significant difference (X^2 test).

Comparisons of the means of food frequency consumption, show very strongly significant differences for all products from beneficial food groups according to the level of adherence to MD. Indeed, frequencies of consumption of these foods were higher in the category with high adherence score to MD (Table 6). For the non-beneficial food products, no difference was shown between both adherence categories. However, the low frequency of meat consumption contributes to a good adherence after a binary logistic regression since the odds are less than 1 and significant (OR=0.595; P=0.01).

Table 6. Daily Means frequency of food consumption by level of adherence to MD.

Food groups FFC/day	Low adherence	High adherence	P-value
Dairy products	0.91±0.05	0.93±0.06	NS
Meat	1.07±0.04	1.11±0.05	NS
Fish	0.15±0.01	0.26±0.02	0.000***
Legumes	0.14±0.01	0.27±0.01	0.000***
Vegetables	2.39±0.11	3.78±0.15	0.000***
All cereals	3.53±0.09	4.20±0.12	0.000***
Olive oil	0.16±0.01	0.23±0.02	0.001**
Fruits and nuts	0.89±0.05	1.45±0.08	0.000***

MD: Mediterranean diet; FFC: Food frequency consumption; **: 0.01<P<0.001; ***: P<0.001; NS: Non-significant difference (t-test).

Table 7 presents the comparison of the frequency of consumption of different food groups according to gender. Women consume more frequently non-beneficial products (dairy products and meat) with significant differences, while they consume less frequently beneficial food products such as fruits (P=0.000). This pattern is reversed in men who adhere more than women (49% *vs* 31.4%). In addition, a binary logistic regression analysis shows that in men, fruits have an odd ration of (OR=1.48; P=0.04) which contribute more to adherence to the Mediterranean diet. Similarly, the odd ration of meat (OR=0.383; P=0.03) whose low frequency of consumption constitutes a protective factor favoring good adherence to the MD. In women, such a clear pattern was not found for the level of adherence to MD.

Table 7. Daily Mean frequency of food consumption by gender.

Food groups FFC/day	**Women**	**Men**	**P-value**
Dairy products	0.99±0.05	0.81±0.05	0.02*
Meat	1.18±0.04	0.97±0.004	0.002**
Fish	0.18±0.01	0.22±0.02	NS
Legumes	0.19±0.01	0.18±0.01	NS
Vegetables	2.98±0.12	2.80±0.15	NS
All cereals	3.81±0.09	3.74±0.13	NS
Olive oil	0.17±0.01	0.22±0.02	NS
Fruits and nuts	0.81±0.04	1.60±0.09	0.000***

FFC: Food frequency consumption; *: 0.05<P<0.01; **: 0.01<P<0.001; ***: P<0.001. NS : Non-significant difference (t-test).

Comparison of the frequency of the various food groups consumption in subjects with high and low adherence to the MD was analyzed using the Mann-Whitney test. This analysis revealed that subjects with low adherence to the Mediterranean diet consumed relatively less beneficial foods such as cereals, fish, legumes, vegetables and fruits. In contrast, individuals in this group consumed more vegetables compared to subjects with high adherence (Table 8). These foods are the pillars of the Mediterranean diet, known for their protective effects against cardiovascular diseases, diabetes and other chronic diseases. Furthermore, the group with high level of adherence to the MD had a higher frequency of consumption of beneficial foods considered to contribute to better overall health and a reduction in the risks of chronic diseases. Conversely, individuals who adhere poorly to the MD consume more meat and dairy products, which are considered non-beneficial foods. In fact, these foods, whose high consumption is often associated with an increased risk of cardiovascular disease, obesity, and other health problems, should be consumed in moderation within the Mediterranean diet. In order to assess the influence of distance from the Mediterranean Sea and the level of adherence to MD, a spatial autocorrelation including six cities of Morocco (El Jadida, Casablanca, Fez, Oujda, Rabat and Khouribga) was made based on geographical data (longitude and latitude) and the adherence scores obtained for each city. The analysis

showed that distance has no significant effect on the eating habits of these populations (P=0.5) with a Morran index (I)=0.18 (Figure 2) and (Table 9).

Table 8. Comparison of Food Group Medians by categories of Adherence to Mediterranean Diet.

Adherence to MD	Low adherence (62.5%)	High adherence (37.5%)	P-value
CF/day	Median and Quartiles [25%-75%]		
Cereals	3.64 [2.78- 4.37]	4.20 [3.49- 4.81]	NS
Dairy products	0.84 [0.28- 1.34]	0.71 [0.48- 1.12]	NS
Fish	0.06 [0.00- 0.26]	0.20 [0.08- 0.36]	0.000***
Meat	1.17 [0.71- 1.52]	1.02 [0.76- 1.32]	NS
Legumes	0.12 [0.00- 0.20]	0.60 [0.14- 0.36]	0.000***
Vegetables	2.46 [1.12- 3.39]	3.41 [2.71- 4.04]	0.000***
Olive oil	0.06 [0.03- 0.14]	0.06 [0.06- 0.14]	0.000***
Fruits	0.62 [0.32- 1.11]	1.15 [0.85- 1.82]	0.000***

CF: consumption frequency; *: 0.05<P<0. 01; **: 0.01<P<0.001; ***: P<0.001; NS: Non-significant difference (Man-Withney Test).

Table 9. Statistical data of a spatial autocorrelation using PASSAGE software.

	Max dist	Pairs 1	E(I)	I	SD	Z(I)	P
Class 1	4.96	1	-0.33	-0.18	0.77	0.67	0.5
Class 2	6.95	2	-0.33	-0.16	0.51	0.33	0.7

Max dist: Maximum distance; I: Spatial autocorrelation index; E(I): Expectation of I (expected value of the spatial autocorrelation index); SD: Standard Deviation; Pairs 1: spatial features used in the analysis; Z(I): Z-score of I (Standardized score of the I index); *: 0.05<P<0.01; **: 0.01<P<0.001; ***: P<0.001; NS: Non-significant difference (Spatial autocorrelation test).

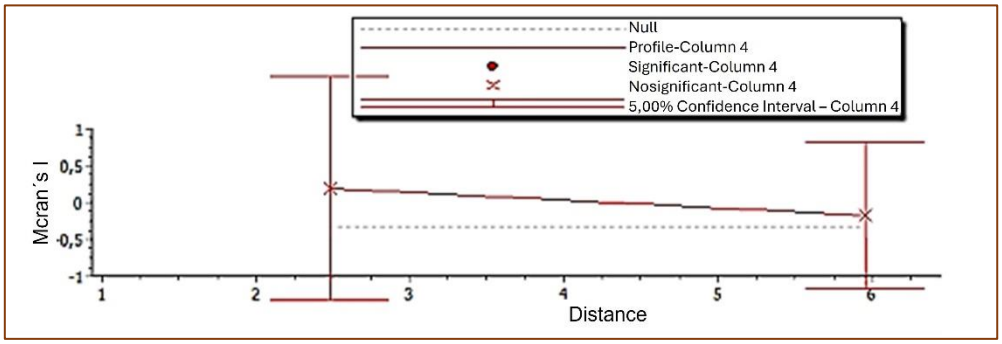

Figure 2. Spatial autocorrelation between six cities in Morocco.

Discussion

This study reports a low adoption of the Mediterranean diet in the Moroccan population of Khouribga province. The study results also revealed an association of low adherence to this healthy diet with the study population profile determinants namely the socio-demographic and economic characteristics, the lifestyle including physical activity level, the eating habits, the body weight management as well as health problems. Indeed, the level of adherence to the Mediterranean diet estimated in this study at 3.91 (SD 0.07) by the MDS adherence score, indicates a low adherence in the population of the study province, with more than 60% of its individuals who do not adhere to this diet reputed to be healthy. Comparing the present results with those of other studies, it appears through the review of the literature data, that a great variability in the level of adherence to MD, is linked to regional differences according to countries and even within a

country, in addition to its link with the various factors specific to each population. Thus, according to a systematic review, the geographical location, including latitude and climate, strongly influences the implementation and adherence to the Mediterranean diet. The geographical proximity to the Mediterranean Sea actually has a significant impact on adherence to the Mediterranean diet (Mattavelli et al.,2022). The explanation of the better tendency of people living closer to the Mediterranean Sea to adhere more to MD has been linked mainly to various factors such as food availability, cultural and traditional influences, social and behavioral factors (Woodside, Young and McKinley, 2022).

In this study, a low level of adherence to the Mediterranean diet was recorded similarly in both residential environments. This result suggests that the living urban vs. rural environment has no significant impact on adherence to the Mediterranean diet. Also, the proportion of individuals in the population who do not adhere to the Mediterranean diet was significant in both the urban and rural populations. This result is inconsistent with those previously reported in another Moroccan province, which showed that rural residents had lower adherence to the Mediterranean diet than those in urban areas of the province of Fez (El Rhazi et al., 2012). Another study in the same province also reported better adherence to this diet among people from urban areas (El Kinany et al., 2018). Data analyses from this study revealed that the gender of individuals was among the multiple factors influencing this adherence to MD, with men adhering more than women to this Mediterranean diet. The same trend is observed in a study carried out on the population of Nador province in the region in the northern and the population of Oujda province in eastern regions of Morocco which found higher adherence to MD among men than among women (Benyaich et al., 2022).In the Emirates and in line with the data of the present study, particularly low levels of adherence to MD have also been reported among women of reproductive age (Naja et al., 2022).

This study also revealed the effect of age on MD adoption. Indeed, compared to individuals in other age groups, those in the 35-50 age group had the highest adherence. This result is not consistent with that obtained in the Moroccan province of El Jadida which showed no difference in MD adherence according to age (Mziwira et al., 2015). In contrast to these data, another study conducted in three countries, Morocco, Palestine and Spain, also reported age as a predictive factor for adherence to the Mediterranean diet in participants aged over 50 years compared to those aged 30 years or younger (Benhammou et al., 2016). The variability of adherence to MD is also demonstrated by the comparison with the results obtained in studies carried out in Spain, Saudi Arabia, Emirates, Algeria and Morocco. A study conducted in Spain by Abellán Alemán et al. (2016) revealed an even lower adherence score in the southeast of the country than that of the present study, while another study carried out in Spain by Olmedo-Requena et al. (2019) revealed an MDS score of 4.3, an MDS slightly higher than that found in the present study. All these results suggest a modest adherence to the Mediterranean diet that still remains insufficient in the regions studied both in Spain and in this province of study. A similar trend of low adherence has also been reported in Saudi Arabia where a recent study by Alnabulsi et al. (2024) indicated that only 21% of the population adheres to the Mediterranean diet.

In this study, the results showing low levels of adherence to MD among women of reproductive age are consistent with those reported in the Emirates (Naja et al., 2022) and confirm the suggestion that some specific populations may have particularly low levels of adherence to this diet. This observation also highlights a limited adoption of this diet in varied cultural and geographical contexts. A comparable trend of low adherence is also observed in several North African countries, indicating a general decline in the adoption of this diet by populations. This is demonstrated by the study carried out in Algeria which revealed that Algerians have largely deviated from the Mediterranean diet (Ouhaibi-Djellouliet al., 2020). This is also the case in Morocco where a large regional variability has been shown through the results of several researches. Indeed, a higher level of adherence to MD than that found in the present study has been reported nationally among Moroccan adults, as expressed by a mean MDS score of 5.1 (El Rhazi et al., 2012). This high adherence contrasts sharply with the score of 3.91 found here, and suggests better adherence at the national level. This overall average of MD adherence highlights gaps in MD adherence in a

population with diversity related to several characteristics including geographic location, residential environment, culture, demographics, and economic factors influencing access and availability of food.

Data from two studies conducted in two other Moroccan provinces in the center of the country, Sidi Bennour (Moustakim et al., 2022) and El Jadida (Mziwira et al., 2024), revealed mean scores slightly higher than that found in the present study but which again indicate low adherence to MD. Contrary to the results of the present study, high adherence to this diet was reported in urban areas of the city of Casablanca (Mohtadi et al., 2020), also located in the same large region as 2 previous provinces (Sidi Bennour and El Jadida). This also indicates diversity and specific differences between provinces in the same country. High adherence to the Mediterranean diet was, on the other hand, revealed among the majority of the population (76%) of Nador and Oujda in the northern and eastern region of Morocco (Benyaich et al., 2022). In line with this, a high level and proportion of adherence to MD exceeding 60% of the population had also been reported by another older study conducted in the province of El Jadida (Mziwira et al., 2015). Comparing the levels and proportions of adherence to MD in the population, higher in studies conducted previously (Mziwira et al., 2015) and lower in the results found recently (Mziwira et al., 2024) in the same Moroccan province of El Jadida, indicate a difference and a trend towards decline in adherence to MD over time. These data highlight a deviation of populations from this healthy diet that could explain the decrease in the protective effect of MD on health and the trend towards the observed increase in chronic diseases in this country.

The present study also shows the link between body weight management and adherence to MD. Indeed, as MD is already known to promote healthy body weight (Serra-Majem et al., 2020), the data reported here show that people with a normal BMI adhere more to the Mediterranean diet than obese people. This result is consistent with literature data reporting that obese individuals adhere less to MD than normal weight individuals (El Rhazi et al., 2012) and that low adherence to the Mediterranean diet has often been associated with high rates of obesity (Moustakim et al., 2022) while high adherence to this diet is associated with a reduction in overweight and obesity and high adherence reduces the risk of obesity (Abellán Alemán et al., 2016; El Kinany et al., 2018).

This study also revealed an association between adherence to MD and lifestyle through data on physical and sedentary activity and eating habits of the population studied. Thus, less sedentary people who took naps of less than 30 minutes adhered more to the Mediterranean diet. This result coincides with that of another study conducted in the population of El Jadida, which had reported a significantly higher rate of adherence to MD among physically active women than among sedentary people (Mziwira et al., 2015). Another lifestyle factor that affects adherence to MD is eating habits. In this regard, the present study revealed that people with low adherence to MD consumed less cereals, fish, legumes, vegetables and fruit while these foods are consumed more frequently by individuals who strongly adhered to this diet. The majority among men and women in the group with low adherence to MD has higher consumption of meat and dairy products, while those with high adherence to MD consumed less. The Mediterranean diet, rich in natural foods (Aboukhalaf et al., 2023; Essaih et al., 2024), low in sodium, is beneficial for cardiovascular health, and its decreased adherence can lead to excessive consumption of salt and saturated fats, contributing to hypertension and cardiovascular events (Trichopoulou et al., 2003; Olmedo-Requena et al., 2019). The beneficial effect of the MD on body weight management (Mziwira et al., 2024) and protection against NCD (Serra-Majem et al., 2020) is related to its rich composition in fruits, vegetables, whole grains and fish. The association of low adherence to the MD with the risk of obesity has been associated with reduced consumption of fish and plant products (Abellán Alemán et al., 2016) as well as an increase in the consumption of processed and high-calorie foods (Barakat et al., 2022). On the other hand, low adherence to this diet has also been associated with an increased prevalence of hypertension as reported by a study conducted by (Abellán Alemán et al., 2016) who found a significant correlation between low adherence and an increase in hypertension.

The present study found that individuals with high adherence to the Mediterranean diet had a lower

mean heart rate, indicating better heart health. This result is in line with the literature data attesting to the protective effect of MD against cardiovascular diseases. This study also established an association between low MDS score and a higher prevalence of hypertension. In addition, heart rate is also elevated in those who adhere less with to MD (P=0.008). Other studies conducted on populations in several countries, including Algeria and Saudi Arabia, have shown that a transition to modern and processed diets is associated with an increased risk of metabolic and cardiovascular diseases (Ouhaibi-Djellouli et al., 2020; Alnabulsi et al., 2024). In addition, the Mediterranean diet is protective against these diseases thanks to its rich content of antioxidants, omega-3 fatty acids and fiber (Benyaich, 2017). Low adherence to this diet is associated with an increased prevalence of diabetes, dyslipidemia, and cardiovascular diseases, as demonstrated in Spanish (Olmedo-Requena et al., 2019) and Saudi (Alnabulsi et al., 2024) studies. On the other hand, high adherence to MD helps reduce the incidence and progression of type 2 diabetes (Zheng et al., 2024). It also has a protective effect against cardiovascular diseases, oxidative stress, dyslipidemia, diabetes mellitus, blood pressure, cancer, neurodegenerative diseases and obesity, this protective effect of the Mediterranean diet is due to the antioxidant, anti-inflammatory compounds and bioactive components contained in foods characteristic of the Mediterranean basin (Aboukhalaf et al., 2023; Essaih et al.,2024), which reduce the risk of developing chronic diseases (Benyaich, 2017).

In conclusion, the data from this study reveal a low adherence to the Mediterranean diet in the surveyed population. The level of adherence to this diet is lower than that of some national studies, but is consistent with the low scores observed in some regions and specific demographic subgroups. The present results report that the percentage of subjects with a low adherence is always higher, with a lower adherence to MD in women than in men, in different age groups, except for the 35-50 age group, in obese people compared to normal weight people, and in sedentary people compared to physically active people. The study data highlight that men and women with high adherence to the Mediterranean diet consume more frequently healthy foods (fruits, vegetables, fish, olive oil), compared to those with low adherence to the Mediterranean diet and less frequently unhealthy foods (dairy products and meats).

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