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RESEARCH ARTICLE

The assessment of Chronic Obstructive Pulmonary Disease (COPD) and its relation to the Mediterranean diet in Moroccan adults - BOLD study

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Authorship

AB conceived the study idea, its design, led the analyses and interpretation of the data, and drafted the manuscript. KE contributed to the conception of the study, and contributed to the review and the editing. IH contributed to the proofreading review and the editing. MMSD and ZH contributed to the conception of the study. ME, CN and MCB contributed to the study design and to the data collection. KE contributed to the study design and to the data collection. Conceived the study idea, its design, and led the analyses and interpretation of the data and supervised the drafting. All authors have read and approved the manuscript.

Abstract

Objective: The protective effect of the Mediterranean diet (MD) is known for several diseases, but the evidence in low- and middle-income countries was still missing. This article assesses the impact of MD and its components on Chronic Obstructive Pulmonary Disease (COPD) among Moroccan adults.

Methods: in population-based cross-sectional study, A total of 744 adults with acceptable spirometry according to the GOLD guidelines were randomly selected from a sample frame, of Moroccan adults lived in the areas of the Saïs district-Fez city. Dietary data were collected through a validated food frequency questionnaire. Mediterranean Diet Score (MDS) was used to assess Adherence to the Mediterranean food model, A value of 0 or 1 has been assigned to each of the eight indicated food components according to their beneficial or deleterious effect on health.

Results: Although no significant associations were found between COPD and the overall MD. score, associations were found between some of the MD components and COPD when stratifying for overall MDS adherence level (low, middle, high adherence). For the high adherence group, the high consumption of cereals, fruits and nuts were inversely associated with COPD risk with OR = 0.64; 95% CI = 0.26-0.89, and OR= 0.67; 95% CI = 0.44-0.96, respectively. The high consumption of meats and dairy products was positively associated with the risk of COPD, with OR = 1.37; 95% CI = 1.22-2.87, and OR= 1.83; 95% CI = 1.21-2.76, respectively.

Conclusion: The results of this study confirmed previous results showing significant associations of COPD risk with some components of MDS. Extensive studies are needed to explore MDS components better and suggest more effective interventions to maintain healthy eating habits and reduce COPD risk.

Introduction

Morocco is a North African country located on the southern shore of the Mediterranean Sea with nearly 34 million inhabitants [1]. This country suffers from the consequences of a deviation from the Mediterranean Diet (MD), and it has experienced a nutritional transition over the past two decades, presented by a shift in its dietary pattern [2], which is associated with an increased burden of non-communicable diseases[3]. Several nutritional and behavioral risk factors such as unhealthy diet, smoking, and irregular physical activity have been suggested as causing illness and lung injuries such as asthma and chronic obstructive pulmonary disease (COPD). According to the world health organization (WHO)[4], COPD is a lung disease presented by chronic obstruction of lung airflow that interferes with normal breathing and is not fully reversible. COPD is among the leading causes of morbidity and mortality worldwide [3]. Its prevalence in Morocco reaches 12.6% of people over 40 [5]. It is the fourth leading cause of death and the fifth leading cause of hospitalization in men [6]. Smoking is the major risk factor for COPD, while MD and its components may play an essential role in preventing this disease [7].

MD consists of a mixture of foods with beneficial or deleterious effects on lung function[8]. Adherence to the MD is described as high consumption of beneficial components, including vegetables, legumes, whole grains, nuts, fruits, olive oil, moderate consumption of dairy products, eggs, poultry, wine, and low consumption of red meat[9]. These beneficial components have anti-inflammatory and antioxidant properties and play an essential role in maintaining the balance between beneficial/deleterious, oxidant/antioxidant, and inflammatory/anti-inflammatory properties[10,11].

Evidence from epidemiological data shows that MD could be a protective factor against pulmonary diseases through its beneficial components, such as phytochemicals with antioxidant properties. As such, MD improves respiratory functions and ameliorates the quality of life of COPD patients[8,12].

Most studies described the association between intake of nutrients or isolated foods and COPD risk. However, it does not appear easy to discern the contribution of one food or one nutrient to the well-being of individuals. Hence, the importance of evaluating the diet as a whole, considering the function of different components (foods and nutrients) cannot be dissociated from the rest of the daily diet. However, complementary approaches providing evidence of the possible modulating effect of dietary patterns on lung health and the protective or deleterious effect of individual dietary factors on the risk of COPD are limited.

In the light of the literature, the relation between nutritional status or eating habits and COPD in Morocco remains uncertain. Therefore, a complete analysis assessing the impact of MD compliance and its components on COPD risk could shed light on the potential of an MD in the battle against the increasing COPD epidemic.

Methods

Study design and Participants

Among adults aged ≥40 years, a BOLD cross-sectional population survey was carried out in Fez city, Morocco[13]. The design and rationale of the BOLD survey methodology have been published elsewhere[14]. Participants were randomly selected, from a sample frame, of Moroccan adults living in the Saïs district. Adults were eligible if they were ≥ 40 years old and lived in a randomly selected household. A total of 760 adults with acceptable spirometry values were included in this study.

Data Collection

The study data was collected through the BOLD questionnaire, developed from pre-existing validated questionnaires and used in international surveys administered by trained staff. The questionnaire includes socio-demographic data: age, gender, and educational level (collected in years and divided into two classes: <6 years of school or ≥ 6 years of school). In addition, data about some potential risk factors were also collected: smoking (classified into three classes: non-smokers, ex-smokers, and current smokers); Body Mass Index (BMI, kg/m2) as a quantitative variable, and the Waist Circumference (WC), which was measured with soft tape at the Middle of the iliac and umbilicus. In addition, abdominal obesity was assessed using the sex-specific WC cut-off points. Normal WC was defined by WC ≤ 102 cm in men ≤ 88 cm in Women, and abdominal obesity (WC>, 102 cm in men and >88 cm in women)[15].

Spirometry

Pulmonary function measurements (FEV1 and FVC) were performed by trained and certified technicians using an NDD easyone spirometer[16] FEV1 (the amount of Forced expiratory volume in one second) refers to the maximum amount of air that the subject can forcibly expire during the first second following maximal inhalation. FVC (Forced vital capacity) refers to the maximum amount of air that can be exhaled when blowing out as fast as possible. FEV1/FVC ratio was used in diagnosing COPD according to the GOLD guidelines[17]. COPD stage 1 or higher was defined as post-bronchodilator Forced Expiratory Volume in 1 second to Forced Vital Capacity (FEV1/FVC) ratio less than 70%. Each spirogram was examined and scored using guidelines from the American Thoracic Society (ATS) and European respiratory society (ERS)[16]. The measurement quality was checked by the Burden of Obstructive Lung Disease (BOLD) Pulmonary Function Reading Center at Imperial College London, UK. Only 760 adults were selected due to conforming to spirometry quality.

Dietary intake assessment

Trained interviewers collected dietary information using a validated Food Frequency Questionnaire (FFQ) that includes 32 food sections and 255 traditional and modern foods commonly consumed in Morocco[18]. Standard units or reference servings were specified for each food. The questionnaire included eight categories of intake frequency, ranging from "never or less than once a month" to "four or more times a day." First, each food intake frequency was converted into an average daily intake for each participant. Next, the information was converted into a daily consumption frequency of each food using a Moroccan food composition table (MFCT) [19] and local household units.

Calculation of the Mediterranean diet score

Adherence to the Mediterranean food model was assessed by calculating the Mediterranean Diet Score (MDS)[9]. The MDS included eight food components (Cereals, Olive Oil, Fruits and Nuts, Legumes, Vegetables, Fish, Meat, and Dairy Product). The alcohol consumption component was removed because it was not applicable due to the cultural context. A value of 0 or 1 has been assigned to each of the eight indicated components according to their beneficial or deleterious effect on health. The gender-specific median of each component was used as a threshold. For foods with a beneficial effect on health, such as vegetables, legumes, olive oil, fruits and nuts, cereals, and fish, a value of 1 is assigned for consumption higher than the median; and for foods with a deleterious effect, such as dairy products and meat, a value of 1 was assigned for consumption lower than the median. The scores for each food component were then added together to obtain a total MDS ranging from 0 (minimum MDS) to 8 (maximum MDS). This MDS was divided into 3 MD-adherence (MDA) categories: Low-MDA (MDS ranged from 1 to 3), Moderate-MDA (MDS 4-5), and High-MDA (MDS 6-8).

Statistical analyses

Descriptive statistics, such as means and frequencies, were performed to describe all variables. Continuous variables were shown as Means ± Standard Deviation (SD), and categorical variables as percentages. Chi-square and Student t-test were used adequately to assess the association between COPD and each of these variables.

Bivariate analysis was used to assess the association between the average weekly servings for the eight MDS components (independent variables) and the COPD status (dependent variable) in the whole population and separately in the three MDA categories. In addition, differences among COPD and non-COPD subjects were evaluated using a Student's t-test.

Crude and adjusted multivariate regression models were used to analyze the association between COPD and the MD as a categorical variable (the high MDA category as a reference group) and as a quantitative variable MDS. These analyses were run for the whole population and also stratified by sex (men adjusted for tobacco (smokers population) while women were not adjusted for tobacco because they are predominantly non-smokers (99%)).

On the other hand, the binary logistic regression models were used to estimate the association between COPD risk and the MD components in the whole population and in each of the three MDA-categories. All adjusted multivariate analyses considered the following potential confounders: age, gender, smoking habits, abdominal obesity, and total energy intake. The low and high estimates of TEI values were excluded from the database (1% at each end of the distribution) to control for total energy intake (TEI) as a potential confounding factor. [20]

All analyzes were performed with SPSS version 21 (SPSS Inc., Chicago, IL, USA). *P*-values lower than 0.05 were considered statistically significant.

Results

In this cross-sectional study, the average age of the 744 participants was 55.2 (± 10.20) years, and there were slightly more women (53.2%) than men (46.8 %). The prevalence of smoking was approximately 9.5% for current smokers (21,0% in men and 0.5% in women) and 17.2% for ex-smokers (36.7% in men and 0.5% in women). The average MDS was 4.38 (±1.21), it was 4.36 (±1.22) in men, and 4.40 (±1.20) in women. Adherence to the MD was mainly moderate to high (37.9% and 39.0%, respectively). The overall prevalence of COPD was 14.1%. It is more prevalent in men (19.2%) than women (9.7%). COPD was more prevalent in the group of subjects with moderate adherence to MD (18.8%) than those with high and Low adherence to MD (12.4% and 9.3%, respectively). The main demographic, clinical, and nutritional characteristics according to the MDA categories are shown in Table 1.

Table 1: Demographics. Clinical and nutritional characteristics according to the three categories of Mediterranean diet adherence (low, moderate, and high); BOLD study. Moroccan Center (N=744)

	Low adherence (MD Score 1-3) N= 172		Moderate adherence (MD Score 4-5) N=282		High Adherence (MD Score 6-8) N=290		P*	P**
Age *(Years) (M±SD)*	53.98	±9.80	56.33	±11.02	54.36	±9.86	NS	0.03
Gender								
Men n (%)	81	47.1%	116	41.1%	147	50.7%	NS	0.01
Women n (%)	91	52.9%	166	58.9%	143	49.3%		
Educational level (Years)								
<6 years	132	76.7%	208	73.8%	220	75.9%	NS	NS
>6 years	40	23.3%	74	36.2%	63	24.1%		
Smoking status								
Current-smokers n (%)	16	9.3%	19	6.7%	29	10.0%		
Ex-smokers n (%)	27	15.7%	44	15.6%	70	24.1%	0.02	<0.01
Non-smokers n (%)	129	75.0%	219	77.7%	191	65.9%		
BMI *(Kg/m²)* (M±SD)	28.19	±5.66	28.20	±5.05	27.41	±5.17	NS	NS
Abdominal-Obesity (WC) n (%)	101	58.7%	160	56.7%	132	45.5%	0.01	<0.001
TEI (Kcal/d)	3496.17	±1042.11	3614. 56	±1056. 49	3878.12	±1115.92	<0.001	<0.001
COPD n (%)	16	9.3%	53	18.8%	36	12.4%	0.01	0.04
FEV1 post *(M±SD)*	2.66	±0.74	2.50	±0.73	2.68	±0.70	0.004	0.002
FVC post (M±SD)	3.36	±0.88	3.22	±0.87	3.43	±0.85	NS	0.01
FEV1 post/FVC post *(M±SD)*	79.15	±6.68	77.31	±8.78	78.34	±8.62	NS	NS

P *: P-value for low compared to high adherence to M.D.; P **: P-value for moderate compared to high adherence to MD: with. Student t-test to compare means for continuous variables; Chi-Square Test for categorical data

TEI: Total Energy Intake in kilocalories per day. BMI: Body Mass Index in kilograms by meters squared.; COPD: Chronic Obstructive Pulmonary Disease; MD: Mediterranean Diet; W.C.: Waist Circumference; FVC: Forced Vital Capacity. FEV1 post: a spirometry post-bronchodilator forced expiratory volume in one second.

In our population, when compared to high MDA, participants with moderate MDA were mainly women, non-smokers, low total energy intake (TEI), high abdominal obesity (WC), low FEV1 and FVC, respectively, and higher prevalence of COPD. In addition, when compared to high-MDA, low-MDA was marked by a high rate of abdominal obesity (WC), a low average of TEI, low FEV1, and low COPD prevalence.

Table 2 presents the mean servings per week for the different food components of the MDS and the mean of TEI according to the three MDA-categories of people with or without COPD. The population's COPD status was marked by a low average serving of cereals, vegetables, fruits and nuts, legumes, and TEI, whereas COPD status was linked to a high average serving of dairy products. The average servings of cereals, vegetables, fruits, and nuts were higher in non-COPD subjects compared to COPD ones in the high as well as the moderate MDA categories. Among low and high-MDA compared to non-COPD subjects, the average servings of dairy products were lower in COPD participants, whereas the average servings of meat were higher in COPD subjects with high-MDA. An increased average TEI was observed in COPD subjects in the moderate-MDA group only.

Table 2. Average weekly servings for the different MDS components and Total Energy Intake in people with or without COPD living in Fez. BOLD study (N = 744)

	All			Low adherence (MD Score 1-3)			Moderate adherence (MD Score 4-5)			High adherence (MD Score 6-8)		
	COPD-	COPD +	p	COPD-	COPD +	p	COPD-	COPD +	P	COPD-	COPD +	p
	639	105		N=165	N=16		N=229	N=53		N=254	N=36	
MDS-components												
Mean (±SD)												
Cereals	21.6±6.08	20.85±5.84	<0.001	20.07±7.59	18.29±8.60	<0.001	21.64±4.94	20.12±5.33	0.04	23.04±5.33	20.99±5.12	0.01
Olive oil	11.30±5.57	11.31±5.89	N.S.	9.86±6.55	10.76±7.31	N.S.	12.14±6.15	11.68±5.76	N.S.	11.13±5.43	10.9±5.45	NS
Vegetables	8.33±3.95	7.81±3.16	<0.001	9.17±3.54	10.31±3.53	NS	7.77±3.85	6.74±3.12	0.01	8.19±4.34	7.95±3.24	0.05
Fruits and nuts	6.65±4.64	5.91±4.2	<0.001	5.95±3.61	6.53±2.24	NS	6.31±3.40	5.49±3.34	0.02	7.13±5.97	6.02±5.98	0.02
Legumes	1.19±1.21	0.94±0.82	<0.001	0.85±0.66	0.7±0.70	NS	0.88±0.72	0.83±0.67	N.S.	2.59±2.34	2.39±1.04	NS
Fish	1.78±1.38	1.95±1.11	NS	1.41±0.99	1.46±0.95	N.S.	1.74±1.07	1.8±1.01	N.S.	1.99±1.75	2.2±1.39	NS
Meat	4.87±2.35	4.77±2.31	N.S.	5.45±3.90	6.74±3.12	N.S.	4.84±1.92	4.86±2.30	NS	3.95±2.17	4.74±2.06	0.03
Dairy products	7.08±5.31	8.22±5.43	<0.01	7.96±7.79	9.3±5.42	0.04	8.78±5.83	8.9±5.77	NS	4.74±4.62	7.36±5.19	0.004
TEI	3744.33±1102.79	3473.5±982.46	<0.001	3522.03±1035.13	3279.29±1053.02	NS	3671.09±1068.86	3345.56±824.35	0.02	3872.39±1057.09	3664.5±1261.80	NS

COPD: Chronic Obstructive Pulmonary Disease; MDS Mediterranean diet Score; SD Standard Deviation; TEI: Total Energy Intake; NS: Not Significant

Associations between the MDA categories and COPD risk are presented in Table 3. No significant associations were found between these MDA categories and COPD risk in the population or both genders. However, significant associations were found between specific components of the MDS and COPD in the whole population and each of the MDA categories (Table 4). Overall, and regardless of age, sex, smoking habits, abdominal obesity as well as total energy intake, there was a statistically significant inverse association between the individual components of the MDS and COPD risk for cereals, fruits and nuts, and vegetables, while a positive association with dairy-products was observed. In addition, the risk of COPD decreased in men for olive oil and legumes and increased for meat. In contrast, these components were not associated with COPD risk in women

Table. 3: Crude and Adjusted models for MDA categories and COPD risk by gender (N=744)

MDA categories	**Model 1** OR (95% CI)	**Model 2** OR (95% CI)
Overall (N=744)		
High MDA* (N=290)	1	1
Moderate MDA (N=282)	1.04 (0.59 ; 1.83)	0.93 (0.51 ; 1.70)
Low MDA (N= 172)	1.22 (0.72 ; 2.08)	1.31 (0.75 ; 2.27)
Men (N=344)		
High MDA (N=147)	1	1
Moderate MDA (N=116)	1.01 (0.49; 2.05)	0.75 (0.35 ; 1.62)
Low MDA (N=81)	1.25 (0.65 ; 2.40)	1.18 (0.60 ; 2.34)
Women (N=400)		
High MDA (N=143)	1	1
Moderate MDA (N=166)	1.43 (0.52 ; 3.90)	1.49 (0.52 ; 4.28)
Low MDA (N=91)	1.52 (0.58 ; 3.99)	1.71 (0.62 ; 4.73)

*Mediterranean Diet Adherence
Model 1: brut odds ratio
Model 2: overall M.D. adjusted for age, gender, smoking habits, abdominal obesity, and total energy intake.
Model 2: In men, adjusted for age, smoking habits, abdominal obesity, and total energy intake (all smokers were men).
Model 2: In women, adjusted for age, abdominal obesity, and total energy intake.

In the low-MDA group, COPD risk decreased with increased cereals consumption. However, this association disappeared when stratified by gender. Moderate-MDA was marked by the inverse relationship between the COPD risk and the consumption of cereals, fruits, nuts, and vegetables, while a positive association was observed with meat consumption. This association remains negative for legumes and vegetables in men but positive for meat and dairy products. Finally, in the high-MDA group, COPD risk was inversely associated with cereals, fruits, and nuts while positively associated with consuming meat and dairy products. By contrast, only olive oil and legumes were inversely associated with COPD risk in men, while dairy products were positively associated with COPD risk in women.

Table 4: Logistic binary regression models of M.D. food categories and their association with COPD in 3 levels of adherence, for the total population and by gender (N=744)

	Whole population	CI 95%	Low Adherence	CI 95%	Moderate Adherence	CI 95%	High Adherence	CI 95%
All&								
Cereals	**0,58**	**(0,38; 0,89)***	**0.57**	**(0.38 ; 0.87)***	**0.66**	**(0.41 ; 0.98)***	**0.64**	**(0.26 ;0.89)***
Olive Oil	1,45	(0,60 ; 3,46)	0.63	(0.27 ; 1.50)	1.08	(0.43 ; 2.71)	0.84	(0.06 ; 10.54)
Fruits and Nuts	**0,56**	**(0,36 ; 0,86)***	1.01	(0.98 ; 1.04)	**0.92**	**(0.91 ; 0.99)***	**0.67**	**(0.44 ; 0.96)***
Legumes	0,96	(0,63 ; 1,46)	0.94	(0.59 ; 1.49)	1.03	(0.66 ; 1.60)	1.13	(0.31 ; 4.04)
Vegetables	**0,84**	**(0,26 ; 0,87)***	1.19	(0.77 ; 1.86)	**0.97**	**(0.96 ; 0.99)***	0.65	(0.07 ; 5.72)
Fish	1,41	(0,66 ; 1,54)	1.86	(0.91 ; 3.82)	1.01	(0.66 ; 1.54)	2.00	(0.55 ; 7.22)
Meat	1,34	(0,88 ; 3,04)	0.97	(0.64 ; 1.47)	**2.10**	**(1.00 ; 4.50)***	**1.37**	**(1.22 ; 2.87)***
Dairy Products	**1,26**	**(1,08 ; 1,89)***	3.77	(0.99 ; 14.24)	0.86	(0.45 ; 1.64)	**1.83**	**(1.21 ; 2.76)***
For Men*								
Cereals	0,73	(0,39 ; 1,37)	0.64	(0.21 ; 1.94)	0.62	(0.23 ; 1.66)	0.40	(0.20 ; 2.75)
Olive Oil	**0,48**	**(0,24 ; 0,95)***	0.72	(0.07 ; 7.94)	0.44	(0.08 ; 2.59)	**0.12**	**(0.06 ; 0.59)***
Fruits and Nuts	1,09	(0,07 ; 17,86)	1.17	(0.51 ; 2.24)	0.52	(0.21 ; 1.31)	0.41	(0.04 ; 5.39)
Legumes	**0,42**	**(0,34 ; 0,94)***	0.66	(0.29 ; 2.14)	**0.34**	**(0.12 ; 0.96)***	**0.13**	**(0.01 ; 0.62)***
Vegetables	0,79	(0,14 ; 4,33)	1.15	(0.39 ; 3.43)	**0.33**	**(0.14 ; 0.79)***	0.82	(0.57 ; 11.97)
Fish	1,39	(0,93 ; 1,88)	1.03	(0.33 ; 3.22)	1.88	(0.77 ; 4.58)	1.84	(0.27 ; 12.85)
Meat	**1,73**	**(1,24 ; 6,19)***	0.87	(0.32 ; 2.35)	**2.30**	**(1.15 ; 5.45)***	2.40	(0.39 ; 8.57)
Dairy Products	1,67	(1,15 ; 5,43)	1.75	(0.59 ; 5.24)	**1.49**	**(1.19 ; 4.71)***	1.26	(0.22 ; 7.38)
For Women¥								
Cereals	0,66	(0,53 ; 1,75)	0.51	(0.10 ; 2.58)	0.51	(0.18 ; 1.48)	0.87	(0.67 ; 2.03)
Olive Oil	0,82	(0,69 ; 5,32)	0.68	(0.32 ; 1.78)	1.08	(0.23 ; 5.82)	1.04	(0.27 ; 6.95)
Fruits and Nuts	0,99	(0,97 ; 1,00)	0.87	(0.24 ; 3.18)	0.57	(0.20 ; 1.62)	0.71	(0.44 ; 1.16)
Legumes	0,92	(0,46 ; 4,15)	0.77	(0.22 ; 2.73)	1.83	(0.63 ; 5.33)	1.23	(0.62 ; 4.24)
Vegetables	0,99	(0,97 ; 1,00)	1.15	(0.28 ; 4.75)	0.89	(0.31 ; 2.59)	0.81	(0.53 ; 3.68)
Fish	1,53	(0,72 ; 3,47)	1.07	(0.31 ; 3.80)	1.75	(0.62 ; 4.96)	2.16	(0.23 ; 6.42)
Meat	1,07	(0,29 ; 5,03)	0.46	(0.14 ; 1.55)	1.25	(0.43 ; 3.64)	1.06	(0.56 ; 5.56)
Dairy Products	1,12	(0,71 ; 5,78)	2.94	(0.71 ; 12.26)	0.66	(0.22 ; 2.03)	**1.75**	**(1.31 ; 3.46)***

*&Regression analysis Adjusted for age, sex, smoking habits, abdominal obesity, and total energy intake; *Regression analysis Adjusted for age, smoking habits, abdominal obesity, as well as total energy intake; ¥Regression analysis Adjusted for age, abdominal obesity, as well as total energy intake.*

Discussion

This cross-sectional study was designed to examine the relationship between COPD, the Mediterranean diet, and its components in Moroccan adults living in Fez. The key findings indicated that, regardless of the MDA category, the risk of COPD decreased with the increased consumption of cereals. The same association was found for fruits and nuts in the whole population, as well as the moderate and high MDA categories, while for vegetables in the whole population and the moderate MDA category only. Interestingly, the COPD risk decreased with the increasing consumption of olive oil and legumes in men only. On the other hand, the COPD risk increased with the increasing consumption of meat in moderate and low-MDA categories and the high consumption of dairy products in the whole population and the high-MDA category.

According to scientific and epidemiological literature, the high MDS reflects high intakes of vegetables, fruit and nuts, whole grains, polyunsaturated fatty acids (PUFA), monounsaturated fatty acids (MUFA), and low intakes of red and processed meat, refined grains, empty calories and sodium[21,22]. Individual consumption of some of these foods has been linked to better lung function, while others have been shown to have a deleterious effect on respiratory function[7]. Several results of previous prospective and retrospective studies[8,12,23] support the hypothesis that greater adherence to the Mediterranean diet and its beneficial components may blunt the adverse respiratory effects and the risk of developing COPD.

In our study, cereals intake was negatively related to COPD status regardless of MDA categories, and this result can be explained by the fact that cereals constitute the main food in almost all Moroccan dishes. In addition, being at the bottom of the MD-Pyramid[21], cereals are the primary source of nutritional energy, protein, iron, vitamins, and fiber [24]. Their potential beneficial effects on human health are numerous: they lower blood cholesterol and glucose levels, reduce toxins and preserve intestinal flora's beneficial balance [25]. Also, their effect on pulmonary functions has been proven by clinical and epidemiological tests as protective factors against smoking effects and repair damaged lung tissue [26,27]. Our study was in line with many others: A prospective study exploring the role of dietary fiber intake and the risk of COPD in American women and men concluded that the consumption of fiber, particularly cereal fiber, was negatively associated with the risk of newly diagnosed COPD [27]. In addition, the MORGEN study [28] suggests a beneficial independent effect of whole grains (> 45g per day) on COPD.

Another finding from our study showed that higher consumption of vegetables, fruit, and nuts, both the main components of the MDS, is associated with improved lung function for moderate and high-MDA. The same results have been confirmed by previous epidemiological literature, according to which the consumption of antioxidants in fresh fruits and vegetables could compensate for the damage caused by tobacco and inhaled particles, could delay the premature aging of the lung, reduce the production of mucosa and therefore also reduce cough[10,29]. Indeed, several epidemiological studies have found that a "prudent" diet, rich in fruits and vegetables, has a beneficial effect on respiratory function, especially FEV1, and is linked to a low prevalence of newly diagnosed COPD[30,31]. Furthermore, other studies have concluded that daily intake of vegetables and fruits can slow the decline in respiratory function even among former smokers[10,31]. For example, a Swedish prospective cohort exploring the effect of fruit and vegetable consumption on the incidence of COPD concluded that each daily serving of fruit and vegetables reduced the risk of COPD by 8% and 4%, respectively, among current and ex-smokers [32]. Another beneficial effect of consuming fruits and vegetables was related to weight gain and obesity controls, known as determinant risk factors for the morbidity-mortality of COPD.

In our study, legumes correlate with COPD status only in men but not in women or the whole population. Legumes are an essential component of a healthy diet and are associated with a reduced risk of COPD[33]. This effect underlies "the Hispanic paradox"[33], relating to the anti-inflammatory effect of legumes (beans and lentils) on the reduction of systemic inflammation, decrease in respiratory symptoms, and eventually lower risk of COPD. Similarly, a low COPD risk has been reported in Asian subjects attributed to increased soy-product consumption[34]. Legumes are found in most Moroccan dishes and are consumed as frequently as cereals [35]. However, household legumes consumption has been declining for years[35]. This fact was confirmed through the current study, where the frequency of their consumption was less than once per week for low and moderate-MDA categories and twice a week for the high-MDA category (1.91 (±0.95) for men and 1.86 (±1.06) for women). The decreased consumption of legumes, mainly in women, may explain the absence of the association with COPD in this study.

Olive oil remains the primary source of dietary fat in Morocco and is incorporated in almost all meals[35]. Our research has shown a decreased COPD risk with higher olive-oil consumption only in men, especially among the high-MDA group. This result may be due to the possible impact of phenolics which affects markers of oxidation and plasma susceptibility to oxidation caused by smoking. Although there is no direct causal relation between olive oil on pulmonary function, there is evidence of a particularly positive effect on improving respiratory functions, such as weight loss, lowering of triglycerides, lipoprotein cholesterol levels, and reduction of blood pressure[36]. For women, and like other studies in the Mediterranean area, no association between olive oil consumption and COPD risk has been found[37], which can be explained by food component interactions during the digestion process.

There were also no statistically significant associations between fish intake and COPD risk. This result was in line with several prospective and longitudinal studies[30,38]. The low consumption of fish may explain our results in the current sample (less than two times a week, which is lower than the recommendations of the MD pyramid[21], and this is because the city of Fez is far away from the sea, and the consumption of fish which is not always affordable is not very widespread. Aside from the nutritional values of fish, its consumption is recognized as protective against chronic conditions due to omega 3 and 6, well known for their antioxidant and anti-inflammatory effects[39]. These unsaturated fatty acids are crucial in restoring respiratory functions, reducing inflammation, and the burden of chronic diseases[30].

Little information about the relationship between dairy intake and lung function is known, especially among COPD patients[40]. In the current study, a significantly positive association between the consumption of dairy products and COPD was found in the whole population and remained the same in the high-MDA category and women. This correlation can be explained by the high-fat content of dairy products eaten more frequently by COPD women (7.39 (±4.73) in Men and 8.94 (±6.16) in Women

P<0.001). Other studies have shown similar results [7,41]. In addition, data-driven dietary trends have shown the adverse impact of a diet rich in high-fat dairy products on respiratory symptoms[7]. Interestingly, it has been shown that the high-fat content of dairy products has been linked to worse respiratory symptoms and lower lung function. Conversely, higher intakes of low-fat dairy products may have a protective effect on lung function, likely through their anti-inflammatory action[40].

Our results on red meat and its derivatives on the deterioration of respiratory function were consistent with those of previous studies[42,43]. In some studies, diets high in red meat and processed meat were associated with impaired respiratory functions (particularly FEV) and a high prevalence of COPD[44]. This happens due to salts and nitrites in meats amplifying the nitrosative stress through the production of nitrogenous reagents, thus contributing to the deterioration of the progression of the pulmonary function. A Chinese cohort found that in COPD, and independently of a diet rich in fiber, diets rich in meat, sodium, and refined carbohydrates, could increase the risk of developing a cough with phlegm.

Although the results might be disaggregated by sex, the underlying data found that COPD risk was only related to men in moderate to high-MDA groups. The high smoking prevalence can explain the gender difference in the high COPD risk among men. Evidence has shown that smoking induces lung function impairment and poor health status[45]. Moreover, smokers tend to adopt an unhealthy diet and consequently have a higher level of oxidative stress[23]. These gender differences may also extend to different food choices and healthy lifestyles[12].

Our study had certain potential limitations, which must be considered. The first one is related to its cross-sectional nature in which the causal relations cannot be determined. The second limitation is linked to the nutritional data collection tool. Although the FFQ used in this study is valid and reliable, it collects data from the last 12 months preceding the interview. Thus, measurement errors could be introduced in the self-declared information. To improve the objectivity of the answers and reduce the possibility of misreporting, the FFQ was administered by trained interviewers who encouraged and helped participants to be more objective. In addition, since the FFQ represents a usual diet, nutritional estimates may be affected by seasonal changes and the risk of underestimating energy intake. However, this FFQ demonstrated correct validity and reproducibility for most nutrients. An advantage of these studies is that the spirometry test was performed according to the BOLD protocol.

Furthermore, the quality of the spirometry tests and the database management system were checked and purified from non-compliant tests and data by the "Respiratory Epidemiology and Public Health Center at Imperial College." Several measurements were considered, including the forced expiratory volume (FEV1), the most important measurement of lung function; it helps assess which level of COPD the patient has entered and gives more accuracy to COPD diagnosis and stages. Also, anthropometric measurements were collected using calibrated materials. Thus, the results could be considered accurate, and a wide range of potential confounding factors was controlled for in the analyses.

Conclusion

This study has followed a complementary approach to assess the association between COPD risk and MD components. It has confirmed previous results showing the significant association of the COPD risk with some components of MDS. However, since diet remains a modifiable lifestyle factor that may contribute to the prevention of chronic diseases like COPD, further extensive studies are needed to explore all MDS components better and shed light on more effective interventions in maintaining healthy eating habits and reducing COPD risk.

Conflict of interest

The authors declare that they have no competing interests.

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List of abbreviations

ATS: American Thoracic Society.

BMI: Body Mass Index.

BOLD: Burden of Obstructive Lung Disease

CI: Confident Interval.

COPD: Chronic Obstructive Pulmonary Disease.

ERS: European respiratory society.

FEV: Forced Expiratory Volume

FEV1: Forced Expiratory Volume in one second

FEV6: Forced Expiratory Volume in six second

FFQ: Food Frequency Questionnaire.

FVC: Forced Vital Capacity

GOLD: Global Initiative for Chronic Obstructive Lung Disease

MD: Mediterranean diet.

MDA: Mediterranean diet Adhearence.

MDS: Mediterranean diet Score.

MFCT: Moroccan food composition table.

OR: Odds-Ratio

SD: Standard Deviation.

TEI: Total Energy Intake

WC.: Waist Circumference.

WHO: World Health Organization

WHR: Waist to Hip Ratio

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