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Research Article

Prevalence of Diabetes and Pre-Diabetes and Its Associated Risk Factors among the Tunisian Population: Results of the ATERA-Survey

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Abstract

Background: The purpose of this study was to describe the prevalence of diabetes mellitus and pre-diabetes and their associated risk factors among the Tunisian population.

Methods: The ATERA-survey was a nationally representative, cross-sectional study conducted between January 2016 and Mars 2019. Sociodemographic and behavioral characteristic data were collected by face-to-face interviews during a door-to-door visit.

Results: 10576 participants (4642 men and 5934 women) aged 25-75 years completed an interview and medical examination. The overall prevalence of diabetes was estimated to be 23.0 % (95% CI, 22.2% - 23.8%) of which 16.6% (95% CI, 14.8% -18.3%) were previously known cases of diabetes and 6.4% (4.5% - 8.2%) were newly detected. The prevalence among men was 23.8% (95% CI, 22.9% -24.6%) and among women was 22.30% (95% CI, 21.5% - 23.0%), as well as 24.5% (95% CI, 22.6% -26.4%) and 18.7% (95% CI, 15.3% - 22%) in urban and rural residents, respectively. In addition, the prevalence of pre-diabetes was estimated to be 21.8% (95% CI, 20.1% - 23.5%) in Tunisian adults; 20.9% (95% CI, 18.4% - 23.5%) in men and 22.4% (95% CI, 20.2% - 24.78%) in women. The prevalence of diabetes and pre-diabetes was higher in older age groups and in persons living in economically developed regions.

Conclusions: Our results indicate that diabetes has become a major public health problem in Tunisia. Urgent measures are needed to prevent diabetes and its related complications.

Keywords: Diabetes; Pre-Diabetes, Prevalence; Risk Factors; Epidemiology; Tunisia

Introduction

Diabetes mellitus (DM) is one of the most common public health problems in both developed and developing countries [1]. The International Diabetes Federation (IDF) estimates that in 2017, 451 million adults worldwide had diabetes, with projections of 693 million cases by 2045 [2]. The aging of the population, socio-economic development, the increasing prevalence of obesity and of a sedentary lifestyle, and the processes of urbanization and

industrialization are considered the principal factors responsible for the increase in the incidence and prevalence of DM around the world.

Pre-diabetes mellitus (Pre-DM), referred to as intermediate hyperglycemia or borderline diabetes, represents the intermediate stage of abnormal glucose metabolism [3]. It is estimated that by 2030, more than 470 million individuals will be pre-diabetic [4]. Twenty-five percent of individuals with pre-diabetes will progress to diabetes in 3 to 5 years, and 70% will eventually progress to diabetes during their life course [5]. Determination of the prevalence of pre-diabetes is important for public health policy as those affected are at high risk of both diabetes and cardiovascular disease [6].

Understanding the epidemiology of DM and Pre-DM is essential to identify public health priorities, to generate policy initiatives and evaluate the effect of services in reducing the individual and social burden of diabetes.

Tunisia is a North African country, situated between Algeria at west and Libya at east. With about 163 000 km^2, it is the smallest in North Africa with 11.721 177 million inhabitants (of which about two third are urban). To date, few population-based surveys in small geographical areas have been undertaken in Tunisia. These surveys have shown that the prevalence of diabetes in individuals aged 20 years and over increased from 9.9 % in 1996 [7] to 15.1% in 2010 [8]. However, no nationally representative, epidemiological study had ever been conducted to provide countrywide prevalence of the various risk factors for cardiovascular disease, including diabetes, hypertension and dyslipidemia. This is the reason behind starting a representative epidemiologic study to evaluate them and their evolution over time. Therefore the ATERA-survey was initiated. Between January 2016 and February 2019, the Tunisian association on study and research on atherosclerosis (ATERA) and the International atherosclerosis society (IAS) made, for the first time a large national study, the ATERA-Survey.

The aim of this study was to determine the nationally representative prevalence of diabetes, pre-diabetes and other main risk factors in Tunisian adults in the age group 25 to 75 years. Furthermore, the associations of anthropometry (body mass index and waist circumference), blood pressure, lipids, physical activity and other lifestyle factors with diabetes have also been examined for this. These finding will be used to inform the Tunisian Ministry of health which can guide health and policy planning.

Patients and Methods

The ATERA-survey conducted in Tunisia was integrated in a collaborative project funded by Pfizer laboratory. The survey was cross-sectional from January 2016 to March 2019 and the target population was adult men and women aged 25 to75 years. The study design, the characteristics of the population and the methodological details of the study have been reported previously [9]. The target population was recruited by random sampling drown by the national institute of statistics. The number of households selected for recruitment 5919. The sampling used a two stage cluster (district, household), according to national Tunisian population census of 2014. Characteristics of households were collected at the beginning of the survey and a screening of individuals living within the household identified the eligible population. The study protocol was carried out according to the Declaration of Helsinki and has been ethically approved by the Tunisian Ministry of Health, the Tunisian Ministry of the interior, the Tunisian National Council of Statistics (visa no 15/2015) and the Ethical Review Committee of the Rabta hospital university. All participants gave their free informed consent, after being thoroughly informed of the purpose, requirements and procedures of the survey. The confidentiality of data was assured and data was analyzed anonymously. The participants received written information about the biochemical results, and medical assistance or advice was given when appropriate.

Exclusion criteria

Individuals who are under prescribed treatment for cancer, who have received an organ transplant, who are known to have autoimmune disease, who have severe liver disease, who have chronic renal failure, pregnant women, will be excluded.

Data collection

Data were obtained at participant's homes by trained interviewers using computer-assisted personal interview software. A standardized questionnaire including demographic and socioeconomic information, personal and family medical history, and lifestyle risk factors. Education level was categorized as college or above, secondary school, elementary school and uneducated. Concerning smoking status, a smoker was defined as a person who

smoked any number of cigarettes regularly or who had any history of smoking in the past. A never smoker was defined as someone who had never smoked. Physical activity was defined as participating in moderate or vigorous activity for 30 minutes or more per day at least 3 days a week. Socioeconomic status, education, occupation and income were also recorded. The interview included questions related to the diagnosis and treatment of diabetes, hypertension, dyslipidemia and cardiovascular events. Information on the perception of different cardiovascular risk factors and awareness of, and drug treatment was also obtained. During the examination, weight and height were measured and body mass index (BMI) was calculated as weight in kilograms divided by height in meters square. BMI categories were defined based on WHO classification on BMI for adults [10], underweight: BMI < 18.5 kg/m^2; normal weight: BMI 18.5 to 24.9 kg/m^2; pre-obese or overweight: BMI 25.5 to 29.9 kg/m^2 and obese: BMI ≥ 30.0 kg/m^2. Central obesity was defined as waist circumference above 102 cm in men and 88 cm in women.

Definition

All baseline participants were screened for DM and Pre-DM according to the American Diabetes Association Standards of Medical Care in Diabetes 2019. Specifically, the diagnostic criteria for DM include (1) FPG (fasting plasma glucose ≥7.0 mmol/L [≥126 mg/d]) or (2) confirmed medication usage from the medication inventory, or self reported use of antidiabetic medications within the past 2 weeks of the examination, (3) HbA1c ≥ 6.5% (48 mmol/mol). The diagnostic criteria for Pre-DM include (1) FPG ≥ 5.6 mmol/L and <7.0 mmol/L, or (2) HbA1c between 5.7% and 6.4%.

Blood pressure was measured using a validated blood pressure machine (Rossmax monitoring). Individuals were requested to take 10 min rest in a sitting position before measurement of blood pressure to reduce variation. Two readings were taken for systolic blood pressure (SBP) and diastolic blood pressure (DBP) in accordance with the WHO hypertension guidelines [11]. People were considered hypertensive if they were already diagnosed by a physician or if they were taking any antihypertensive medication or if the systolic blood pressure was ≥ 140 mm Hg and/or diastolic blood pressure ≥ 90 mm Hg. Pre-hypertension is defined as SBP of 120-139 and DBP 80-89 mmHg. Blood samples to test triglycerides (TG), total cholesterol (TC), high-density lipoprotein (HDL-C), and low-density lipoprotein (LDL-C) were also taken from all respondents. The cut-off levels were used according to the suggestions of the National Cholesterol Education Program Adult Treatment Panel III [12]. Dyslipidemia was classified as one or more of the following conditions are fasting state: serum cholesterol > 200 mg/dl, serum LDL-C > 1 30 mg/dl, serum HDL-C < 40 mg/dl, and 50 mg/dl for male and female, respectively, and serum triglycerides > 150 mg/dl. People were also considered as dyslipidemic if they were taking any lipid-lowering medications.

Dietary assessment

All subjects were interviewed about their food intake and dietary habits by a trained nutritionist.

Biochemical assessment

Blood samples were collected after a 12h overnight fast, by using sterilized disposable vacutainer tubes containing sodium fluoride (for glucose), EDTA K_2 (for hemoglobin A1c: HbA1c and NFS) and sodium heparin (for lipids). Blood hemoglobin A1c (HbA1c) was assessed by a competitive turbidimetric inhibition immunoassay method (Tina-quant HbA1c Gen.2) using a Cobas 400 plus analyzer (Roche Diagnostics Ltd., Rotkreuz, Switzerland). Plasma glucose, creatinine, uric acid, total cholesterol, urea, HDL cholesterol, triglyceride and Alanine (ALT) and Aspartate (AST) aminotransferases were assessed by colorimetric methods using an Architect C8000 analyzer and the respective reagents kits (Abbott Laboratories, Abbott Park, IL). LDL cholesterol was calculated using the Friedwald formula [13].

Statistical analysis

The categorical variables were described by the frequencies and the percentages of the valid values. Continuous variables were described by the mean and standard-deviation. No imputation of missing values was done. Confidence intervals were computed based on 95% on confidence. Statistical tests were performed at a level of significance of 5%. Frequencies were compared using Chi-Square test or its correction of continuity in case of theoretic values less than 5. Means were compared by the One-way Anova test, or by Kruskal-Wallis test when the continuous variables distribution wasn't found normal. Kolomogorov-Smirnov test was used normality distribution testing.

Results

Sample characteristics

Among the 5919 households sampled, 11853 subjects aged 25-75 years were contacted for the study. Participants who failed to attend the interview or did not complete the questionnaire (608) (demographic or nutritional) were excluded. Additionally, participants without a blood biochemical measurement and who did not complete the health examination (669) were excluded from the analysis. The response rate was 89.2%. Data from 10576 subjects were used for prevalence estimation, with 7763 (73.4%) participants living in urban areas and 4642 (43.9%) of participants being men. Descriptive characteristics of the study population are given in table 1. The mean age of the participants was 51.33 ± 13.14 years old. There was significant difference in mean age between men and women (52.75 ± 13.39 years vs. 50.23 ± 12.82 years, p < 0.001). 4259 subjects were overweight (40.3%) and 3074 (29.1%) were obese. About 22.4% of the population was illiterate; the rate of illiteracy was higher in women than in men (29.9 *vs*. 12.9%). No difference for higher education levels between men (11.3%) and women (9.3%). Smoking rate was 22.7% (40.0% in men vs. 9.2% in women, P < 0.001). The proportion of participants who self-reported a history of hypertension and dyslipidemia was 44.2% and 48.5%, respectively. Family history of diabetes, defined as having at least one parent or sibling with diabetes, was reported in 50.1% of participants.

	Total		Male		Female		P-value[a]
	n	%	n	%	n	%	
Region							< 0.0001
District of Tunis	2965	28.0	1334	28.7	1631	27.5	
North East	1835	17.4	837	18.0	998	16.8	
North West	1085	10.3	500	10.8	585	9.9	
Centre East	2402	22.7	1049	22.6	1353	22.8	
Centre West	991	9.4	438	9.4	553	9.3	
Southeast	846	8.0	298	6.4	548	9.2	
Southwest	452	4.3	186	4.0	266	4.5	
Place of residence							0.503
Urban	7763	73.4	3407	73.4	4356	73.4	
Rural	2813	26.6	1235	26.6	1578	26.6	
Age in years							< 0.0001
Mean ± S.D; Overall age (years)	51.33 ±13.14		52.75 ± 13.39		50.23 ±12.82		
25-34	1377	13.0	550	11.8	827	13.9	
35-44	1976	18.7	766	20.4	1210	20.4	
45-54	2598	24.6	1057	22.8	1541	26.0	
55-64	2750	26.0	1265	27.3	1485	25.0	
65-75	1875	17.7	1004	21.6	871	14.7	
Education level							< 0.0001
No formal schooling	2371	22.4	599	12.9	1772	29.9	
Primary	4174	39.5	1911	41.2	2263	38.1	
Secondary	2959	28.0	1609	34.7	1350	22.8	
University	1072	10.1	523	11.3	549	9.3	
Professional activity							< 0.0001
Employee/Worker	3860	36.7	3048	66.0	872	13.8	

Unemployed	582	5.2	407	3.0	175	3.0	
Retired	1290	12.3	1122	24.3	168	2.8	
Student	66	0.6	24	0.5	42	0.7	
Housewives	4716	44.9	4716	80.0	-	-	
Prevalence of weight categories							< 0.0001
Under weight, BMI < 18.5 kg/m^2	325	3.1	171	3.7	154	2.6	
Normal weight BMI < 25 kg/m^2	2918	27.6	1530	33.0	1388	23.4	
Overweight, BMI = 25.0 - 29.9 kg/m^2	4259	40.3	1982	42.7	2277	38.4	
Obesity, BMI ≥ 30 kg//m^2	3074	29.0	959	20.6	2115	35.6	
	Total		Male		Female		P-value
	n	%	n	%	n	%	
Current smoking	2399	22.7	1856	40.0	543	9.2	< 0.0001
Physical activity							< 0.0001
Low	5034	47.6	2420	52.1	2614	44.1	
Medium	4389	41.1	1610	34.7	2779	46.8	
High	1153	10.9	612	13.2	541	9.1	
Prediabetes	2303	21.8	971	20.9	1332	22.4	0.1624
Diabetes	2428	23.0	1321	22.3	1107	23.8	0.1502
Dyslipidemia	5125	48.5	2256	48.6	2869	48.3	0.406
HTA	4678	44.2	2166	46.7	2512	42.3	< 0.0001

Table 1: Characteristics of the study population (n = 10576).

[a]Comparison between female and male; mean values were compared using Student's *t*-test. Percentages were compared with Chi-square test.

Prevalence of diabetes and pre-diabetes

Table 2 shows the prevalence of people diagnosed with diabetes and pre-pre-diabetes, stratified by age, gender, residency (urban or rural) and socio-demographic characteristics. The overall diabetes prevalence was 23% (n = 2428), 16.6% (n = 1752) had been previously diagnosed, and 6.4% (n = 676) were newly diagnosed. There was no significant difference between men and women (23.8% *vs.* 22.3%) . In contrast, the prevalence of diabetes was significantly higher among urban than rural residents (24.5% versus 18.7%). The mean age was 56.8 ± 8 years (57.9 ± 9 years in men and 55.9 ± 9 years in women, P < 0.001). The prevalence of diabetes increased significantly with age in both sexes , from 7.8% among those aged 25 – 34 years up to 35.3% among those 65+ years. The frequency of patients with a known family history of diabetes was 64.5%. Hypertension, overweight, obesity and dyslipidemia are present in 67.3%, 42.5%, 29.4% and 67.3% respectively. Diabetes was more prevalent among illiterate group (24.9%) in comparison with higher education level groups (16.7%), and this association was clearly pronounced among women (34.2%).There was a significant difference (p < 0.001) according to region of residence, the highest prevalence was observed in people resident in Greater Tunis (23.8%), Northeast (24.6%), Center-east (23.4%) and Southeast (27.0%) compared to Northwest (17.6%), Center-west (17.4%) and Southwest (25.9%) regions.

The estimated prevalence of pre-DM was 21.8% (95% CI, 21.1% - 23.5%) in the overall population, with 20.9% (95% CI, 18.4% - 23.5%) in men and 22.4% (95% CI, 20.2% - 24.7%) in women. Prevalence of pre-DM is shown to be increasing with increasing levels of BMI as 16.8%, 21.7%, and 26.8% for normal, overweight, and obesity levels, respectively. The prevalence of pre-DM is shown to be increasing proportionally with increasing age as 14.6%, 18.4%, 22.6%, and 26.5% for age group 25-34, 35-44, 45-54, and 65–75 years respectively. Pre-DM was more prevalent in rural 23.1% (95% CI, 19.9% - 26.4%) than in urban residents 21.3% (95% CI, 19.3% - 23.3%), though not significant (Table 2).

	Not diabetic		Pre-diabetic			Diabetic		
Variable	**n**	**% [95%CI]**	**n**	**% [95%CI]**	**P**	**n**	**% [95%CI]**	**P value**
Overall	5845	55.3 [54 - 56.5]	2303	21.8 [20.1 - 23.5]		2428	23.0 [21.3 - 24.6]	
Sex					0.1624			0.1502
Men	2564	55.2 [53.3 - 57.2]	971	20.9 [18.4 - 23.5]		1107	23.8 [21.3 - 26.4]	
Women	3281	55.3 [53.6 - 57.0]	1332	22.4 [20.2 - 24.7]		1321	22.3 [20.0 - 24.5]	
Residence Area					0.8136			< 0.001
Urban	4208	54.2 [52.7 - 55.7	1652	21.3 [19.3 - 23.3]		1903	24.5 [22.6 - 26.4]	
Rural	1637	58.2 [55.2 - 60.6]	651	23.1 [19.9 - 26.4]		525	18.7 [15.3 - 22.0]	
Region					< 0.001			< 0.001
District of Tunis	1609	54.3 [51.8 - 56.6]	649	21.9 [18.7 -25.1]		707	23.8 [20.7 - 27.0]	
North East	952	51.9 [48.7 - 55.1]	432	23.5 [19.5 - 27.5]		451	24.6 [20.6 - 28.6]	
North West	663	61.1 [57.4 - 64.8]	231	21.3 [16.0 - 26.6]		191	17.6 [12.2 - 23.0]	
Centre East	1310	54.5 [51.8 - 57.2]	530	22.1 [18.5 - 25.6]		562	23.4 [19.9 - 26.9]	
Centre West	574	57.9 [53.9 - 62.0]	245	24.7 [19.3 - 30.1]		172	17.4 [11.7 - 23.0]	
South East	459	54.3 [49.7 - 58.8]	159	18.8 [12.7 - 24.9]		228	27.0 [21.2 - 32.7]	
South West	278	61.5 [55.8 - 67.2]	57	12.6 [4.0 - 21.2]		117	25.9 [17.9 - 33.8]	
Age group					< 0.001			< 0.001
25 - 34	1068	77.6 [75.1 - 80.1]	201	14.6 [9.7 - 19.5]		108	7.8 [2.8 - 12.9]	
35 - 44	1345	68.1 [65.6 - 70.6]	364	18.4 [14.4 - 22.4]		267	13.5 [9.4 - 17.6]	
45 - 54	1480	57.0 [54.4 - 59.5]	586	22.6 [19.2 - 25.9]		532	20.5 [17.0 - 23.9]	
55 - 64	1234	44.9 [42.1 - 47.6]	656	23.9 [20.6 - 27.1]		860	31.3 [28.2 - 34.4]	
65 - 75	718	38.3 [34.7 - 41.8]	496	26.5 [22.6 - 30.3]		661	35.3 [31.6 - 38.9]	
Level of education					< 0.001			< 0.001
No formal schooling	1193	50.3 [47.5 - 53.2]	588	24.8 [21.3 - 28.3]		590	24.9 [21.4 - 28.4]	
Primary school	2244	53.8 [51.7 - 55.8]	902	21.6 [18.9 - 24.3]		1028	24.6 [22.0 - 27.3]	
Secondary school	1732	58.5 [56.2 - 60.9]	596	20.1 [16.9 - 23.4]		631	21.3 [18.1 - 24.5]	
University	676	63.1 [59.4 - 66.7]	217	20.2 [14.9 - 25.6]		179	16.7 [11.2 - 22.2]	
Professional activity					< 0.001			< 0.001

Employee/Worker	2321	60.1 [58.1 - 62.1]	794	20.6 [17.8 - 23.4]		745	19.3 [16.5 - 22.1]	
Unemployed	105	16.3 [9.2 - 23.4]	105	16.3 [9.2 - 23.4]		120	18.6 [11.7 - 25.6]	
Retired	516	40.0 [35.8 - 44.23]	310	24.0 [19.3 - 28.8]		464	36.0 [31.6 - 40.3]	
Student	52	78.8 [67.7 - 89 .9]	7	10.6 [12.2 - 33.4]		7	10.6 [12.2 - 33.4]	
Housewives	2537	53.8 [51.9 - 55.7]	1087	23.0 [20.5 - 25.6]		1092	23.2 [20.7 - 25.7]	
Obesity category					< 0.001			< 0.001
Under weight,BMI < 18.5 kg/m^2	200	61.5 [54.8 - 68.3]	64	19.7 [9.9 - 29.4]		61	18.8 [9.0 - 28.6]	
Normal weight BMI < 25 kg/m^2	1998	68.5 [66.4 - 70.5]	490	16.8 [13.5 - 20.1]		430	14.7 [11.4 - 18.1]	
Overweight BMI = 25.0 - 29.9 kg/m^2	2301	54.0 [52.0 - 56.1]	929	21.7 [19.1 - 24.4]		1032	24.2 [21.6 - 26.8]	
Obesity, BMI ≥30 kg/m^2	1346	43.8 [41.1 - 46.4]	823	26.8 [23.7 - 29.8]		905	29.4 [26.5 - 32.4]	
Physical activity					< 0.001			< 0.001
Low/Absent	2685	53.3 [51.5 - 55.2]	1072	21.3 [18.8 - 23.7]		1277	25.4 [23.0 - 27.8]	
Medium	2445	55.7 [53.7 - 57.7]	973	22.2 [19.6 - 24.8]		971	22.1 [19.5 - 24.7]	
High	715	62.0 [58.5 - 65.6]	258	22.4 [17.3 - 27.5]		180	15.6 [10.3 - 20.9]	
Hyperyension	1906	32.6 [30.5 - 34.7]	1137	49.4 [46.5 - 52.3]	< 0.001	1635	67.3 [65.1 - 69.6]	< 0.001
Dyslipidemia	2226	38.1 [36.1 - 40.1]	1266	55.0 [52.2 - 57.7]	< 0.001	1633	67.3 [65.1 - 69.5]	< 0.001
Family history of DM	2607	44.6 [42.7 - 46.5]	1125	48.8 [45.9 - 51.8]	0.005	1567	64.5 [62.2 - 66.9]	< 0.001

Table 2: Prevalence of diabetes and pre-diabetes according to different diagnostic criteria.

Discussion

The findings of our large national survey indicate that diabetes has become a major public health problem in the general population of Tunisia. Our study estimated that approximately 23% of Tunisian adults aged 25-75 years may have had diabetes in 2019 (23.8% in men and 22.8 % in women), which included 16.6 % previously diagnosed DM and 6.4% newly diagnosed In addition, the prevalence of pre-DM in the present study was 21.8% (men: 20.9% and women: 22.4%), which is an important risk factor for the development of overt diabetes and cardiovascular disease. The aging of the population, urbanization, sedentary lifestyle that have occurred with industrialization, changes in diet with increased with popularity of fast foods, decreasing levels of physical activity, with a consequent epidemic of obesity, and the presence of hypertension have probably contributed to the rapid increase in the diabetes burden in the Tunisian population. Similar to our results, several studies have reported high rates of prevalence of DM, such as in Kingdom of Saudi Arabia (31.6%) [14] followed by Oman at 29%, [15], Pakistan [16], Bahrain at 25.5 % [17], Kuwait at 25.4% [18], United Arab Emirates at 25.0% [19], Malaysia 22.9% [20], Lebanon 18.9% [21], Libya 18.8% [21], Jordan 17.4%, [22], Egypt 17% [23], Qatar 16.7% [24], Syria 15.6% [25] Algeria 14.2% [26], Spain 13.8% [27], USA 12%-14% in 2011-2012 [28], Morocco 12.4% [29], and China 11.6% [30]. However, the lowest prevalence was observed in Iran (6.9%) [31], Ethiopia 6.8% [32], Thailand 6.7% [33], UK 5.26% [34], Mauritania 4.7% [35], Brazil 4.4% [36] and

Somalia 3.9% [37]. The comparison between these prevalence's should be done with caution because of different diagnostic criteria used, study designs, and different approaches for obtaining representative samples have been performed.

Our study showed that the prevalence of DM and pre-DM increases with increasing age of the participants. We found a lower DM prevalence of 7.8% among individuals aged 25-34 years; however, the prevalence reached 35.3% among participants 65-75 years. This further supports the extant literature on the association of aging with an increasing prevalence of DM at population level [38,39]. Aging is known to be associated with increased adiposity and decreased muscle mass due to the usually noted decrease of physical activity. Such changes are reported to lead to decrease insulin sensitivity, predisposing individuals to metabolic syndrome or diabetes.

Relation between gender and prevalence of DM showed a mixed result and geographical location has been found as a key determinant. No significant differences were found in our study with regard to sex. This finding was in accordance with a previous review that concluded that there was inconsistent association between sex and diabetes [40].

In the present study family history of diabetes was significantly higher among diabetics than non-diabetics. Subjects with family histories of diabetes presented DM and pre-DM prevalence's of 64.5% and 48.8%, respectively, while for non-diabetics it was 44.6%. Similarly, the prevalence of DM was higher among participants with a high level of dyslipidemia. This is in line with the explanation that individuals with elevated levels of total triglycerides as well as raised low-density lipoprotein (LDL) cholesterol levels are at high risk of developing DM [41].

Associations between the education level and the risk of DM and pre-DM are inconsistent in the literature. We found that participants with DM and pre-DM had lower education levels compared to the normal participants in our study. This finding was supported by other studies and may be due to people with more education having a better awareness about glycemic control and a higher inclination to maintain a healthy lifestyle [42]. In contrast, some studies presented an opposite finding, suggesting that people with a higher education level had a higher DM prevalence, partly due to earlier detection of the disease [43,44]. Another study in China found that the prevalence of diabetes was generally unaffected by educational level but was higher in the high-income group [45].

In our study, obesity was significantly associated with diabetes. Obesity is the most cause for a majority of no communicable diseases in the world and is becoming a public health issue. It is increasing at an alarming rate, as reported by study conducted in different populations. Similarly, in our study 24.2% of the diabetics were found to be overweight, while 29.4% were obese. Increasing obesity was found strongly associated with diabetes ($p < 0.001$). Obesity may lead to increased production of adipokines/cytokines which contribute to insulin resistance and reduced levels of adiponectin which works as an insulin sensitizer [46]. Obesity is also associated with fat deposition, particularly in the liver which leads to increase insulin resistance. Mitochondrial dysfunction is a significant underlying defect that links obesity to diabetes.

Consistent with previous studies, the risk of DM and pre-DM was greater in individuals with hypertension than in those without [47,48]. The present study showed that the prevalence of hypertension among diabetics and pre-DM was found to be 67.3% and 49.5% respectively. The pathophysiological mechanisms that explain the association between hypertension and DM include high blood pressure induced microvascular dysfunction and altered endothelial dysfunction, which have been found to be independent predictors of diabetes.

Another important finding was that the prevalence of DM varied significantly according to Tunisian regions, being higher in coastal regions and lower in interior regions. It was found that the prevalence of diabetes was higher in the North East, Centre East, and the South East regions. The differences in the prevalence of diabetes between regions might be explained by factors such as differences in socioeconomic status, physical activity, dietary patterns and obesity prevalence. The coastal regions have achieved a sustainable socioeconomically development while the North West, the Mid-West and the South West have only recently emerged from poverty and are still less developed regions. The present study demonstrates differential changes in diabetes prevalence by area of residence. The prevalence of diabetes in urban populations 24.5% (95% CI, 22.6% - 26.4%) is significantly higher than rural

populations 18.7% (15.3% - 22.0%). A higher prevalence of DM in urban than rural areas is reported in most countries across the world [49]. Urbanization is related to changes in eating habits, physical activity and smoking, which are risks factors for obesity and diabetes. Conversely, the prevalence of Pre-DM was more prevalent in rural 23.1% (95% CI, 19.9% - 26.4%) than in urban residents 21.3% (95% CI, 19.3% - 23.3%), though not significant.

Strengths and limitations of the study

Our study has several strengths and limitations. The main strength of this study: it is the first study on diabetes to include 24 governorates in Tunisia, both rural and urban populations, and it is the largest epidemiological study of diabetes in the country to date. In addition, the finding provides detailed information on a wide range of risk factors for diabetes and has provided a complete national picture of diabetes situation in Tunisia. Moreover, a robust tool for assessing diabetes status (i.e., HbA1c) was used, which has been used as an authentic marker for evaluating the presence of this disease. Because fasting plasma, glucose can usually detect only a certain proportion of individuals with T2D. In another hand, all blood biochemistry measurements were performed in the same centre using identical procedures, following a strict quality assurance and control program to ensure data validity and reliability.

This study also has several limitations. 1, we did not distinguish between type 1 and type 2 diabetes in this study. Nevertheless, type 2 diabetes is the predominant form of diabetes in adults. 2, all the glycemic markers in the survey were measured only once for each participant, although the guideline for diagnosing diabetes required confirmation by repeated testing. 3, we did not use an oral glucose tolerance test, and thus cases of T2D who have isolated high post-challenge glucose were not identified. 4, nonresidents such as college students and workers and residents less than 25 years old were not included in the study because of the sampling design. These groups were more likely to be healthy and young, with a lower incidence of diabetes, which could lead to the overestimation of diabetes in the population. 5, because of missing data on important information, 1277 participants (10.8%) of the total sample) were excluded from analysis; their exclusion could have affected the estimates. 6, sample size in the rural area was relatively small, since most of the residents still live in urban areas. Finally, participation after the initial invitation varied by regions, with lower initial acceptance in urban than in rural regions. These differences could have differentially affected prevalence estimates in urban and rural environments.

Conclusions

The present study indicates that the prevalence of diabetes in Tunisia is 23%. The aging of the population, urbanization, nutritional changes, and decreasing levels of physical activity, with a consequent epidemic of obesity, have probably contributed to the rapid increase in the diabetes burden in the Tunisian population.

Considering the large number of people with diabetes, Tunisian health officials should include the diabetes preventive measures in their national health policy to minimize the burden of the disease. Public education, regular physical exercise, nutritional knowledge of foods must be provided to the community to control diabetes in the country. Interventions like weight management, increased physical activity, increased fruits and vegetables consumption are required and recommended.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Riadh Jemaa designed and managed the project and wrote the manuscript. Amani Kallel was involved in data collection and review/editing of the manuscript. The statistical analyses were performed by Dr Rabie Razgallah . All authors read and approved the final manuscript.

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