Investigating the association of tobacco smoking with obesity, hyperglycemia, high blood pressure, and dyslipidemia in Moroccan adults: Findings from a nationally representative cross-sectional survey

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ABSTRACT

INTRODUCTION There has been a reduction in tobacco smoking worldwide except in developing countries, where progress in addressing its harms has been slow. We aimed to estimate smoking prevalence and investigate its association with obesity, hyperglycemia, high blood pressure, and dyslipidemia in Moroccan adults.

METHODS This is a secondary dataset analysis of the 2017 STEPS-survey. Data were collected using the WHO STEPwise approach to surveillance (STEPS). A total of 4580 adults were included in our analysis. Bivariate and multivariate logistic regression analyses, with adjusted odds ratios (AOR) for confounding variables, were used to assess the association between smoking and targeted health disorders.

RESULTS The overall smoking prevalence was 7.7%. Smoking status was significantly associated with gender, age, education level, marital status, weight status, blood glucose, HDL-cholesterol, triglycerides, physical activity, and alcohol consumption ($p<0.05$). Current smoking prevalence was higher among men, and in less educated individuals, than in women and those with high level of education. Married and non-drinker individuals showed a higher prevalence of smoking compared to single/separated/widowed individuals and alcohol drinkers ($p<0.05$). Compared to never smokers, both current and former smokers tended to have higher odds of being overweight/obese (AOR=1.08; 95% CI: 0.81–1.64 and AOR=1.22; 95% CI: 0.87–1.56, respectively). They also had a significantly higher likelihood of low HDL cholesterol (AOR=1.59; 95% CI: 1.19–2.10, and AOR=1.40; 95% CI: 1.13–1.85, respectively). However, they were significantly less likely than never smokers to have hyperglycemia (AOR=0.64; 95% CI: 0.42–0.89, and AOR=0.60; 95% CI: 0.37–0.80, respectively) and hypertriglyceridemia (AOR=0.72; 95% CI: 0.39–1.00, and AOR=0.69; 95% CI: 0.46–0.90, respectively).

CONCLUSIONS Smoking was common among the study population and was associated with various sociodemographic, behavioral, and health factors. Current and former smoking were associated with a higher likelihood of low HDL cholesterol and being overweight/obese, as well as a reduced likelihood of hyperglycemia and hypertriglyceridemia. Our findings underscore the need for effective interventions to promote smoking cessation and address smoking-related comorbidities.

INTRODUCTION

Over the last few decades, the alarming rise in the prevalence of non-communicable diseases (NCDs) has become a major public health issue worldwide. NCDs are recognized as the

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leading cause of global morbidity and mortality, accounting for approximately three-quarters of deaths that occur each year. Most of these deaths are due to cardiovascular diseases, cancers, diabetes, and respiratory diseases, which are responsible for over 80% of all premature deaths related to NCDs[1].

The World Health Organization (WHO) reported that 86% of all NCD-related deaths occur in low- and middle-income countries (LMICs)[1]. In Morocco, a lower middle-income country in North Africa, NCDs account for 84% of total deaths, making it one of the countries with the highest NCD mortality rates in the Eastern Mediterranean Region[2]. The leading causes of death in Morocco are cardiovascular diseases (38%), cancers (14%), diabetes (6%), and chronic respiratory diseases (4%)[3].

Smoking is one of the most well-established risk factors for NCDs[4]. The relationship between smoking status and NCDs is complex, with smoking contributing to the pathogenesis of multiple physiological conditions. This occurs through mechanisms such as inflammation, oxidative stress, and vascular damage that play key roles in the onset of many NCDs[5].

Despite widespread awareness of its detrimental health effects, tobacco consumption remains prevalent worldwide, particularly in LMICs, where more than 80% of the world's 1.3 billion tobacco users live[6]. Therefore, further studies are needed to understand how smoking status (current, former, or never smoker) correlates with the broader spectrum of NCDs across different adult populations and to contribute to the development of more effective policies for tobacco control and disease prevention.

In this context, the Moroccan Ministry of Health and Social Protection conducted in 2017–2018 a nationwide cross-sectional survey on risk factors for NCDs (Morocco STEPS 2017–2018). The objectives of the current study were to estimate the prevalence of smoking and investigate its association with obesity, diabetes, hypertension, and dyslipidemia among adults aged 18–100 years.

METHODS

Study design and data source

In this secondary dataset analysis, we used data from the first national STEPS survey carried out in 2017–2018[7]. This was a cross-sectional study designed to choose a representative sample of adults aged 18–100 years from all regions in Morocco. A multi-stage, stratified, and geographically clustered sampling design was used. The sample size was determined using the 2014 General Population Census, ensuring representativeness, with an overall response rate of 89%[7]. It was derived from the master sample based on four-stage selection procedure: 1) 244 primary sampling units (PSUs) were selected, with 158 from urban areas and 86 from rural areas, out of a total of 4500 PSUs in the master sample; 2) one secondary sampling unit (SSU) was chosen from each PSU, with each SSU typically containing 50 households (averaging 300 households per PSU); 3) systematic sampling was conducted to select households; and 4) in each household one adult member meeting the selection criteria was randomly selected. More details on sample size calculation are presented elsewhere[7].

Data collection

Trained investigators collected the data following the standardized WHO STEPwise methodology for monitoring NCD risk factors[8]. The investigators recorded the data using electronic tablets and conducted measurements at the participants' homes.

Collection of sociodemographic and behavioral data

A standardized WHO questionnaire was used to collect sociodemographic data, such as age, gender, marital status, education level, residence, and professional status, as well as behavioral information regarding tobacco and alcohol use, physical activity, and fruit and vegetable consumption. Participants were categorized as either physically active or inactive based on the WHO recommendations[9]. The assessment of fruit and vegetable intake followed the WHO guidelines[10], which suggest a minimum daily consumption of 400 g, corresponding to 5 servings of fruit and vegetables, or 2 servings of fruits and 3 servings of vegetables, with each portion weighing 80 g.

Physical measurements

Anthropometric measurements were performed using standardized methods and equipment; more details are presented elsewhere[11]. Body mass index (BMI, kg/m^2) was calculated as the ratio of weight (kg) to height squared (m^2). Based on the WHO criteria, the weight status of each participant was categorized as: underweight <18.5, normal weight 18.5≤ to <25, overweight 25≤ to <30 or obese ≥30). Abdominal obesity was defined as waist circumference >94 cm for men and >80 cm for women.

Participants' blood pressure was measured three times in a seated position, without their legs crossed, and the cuff was correctly placed to ensure accurate readings. The average of the measurements was used to categorize it according to the guidelines of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC7)[12]: normal blood pressure, prehypertension [systolic blood pressure (SBP) of 120–139 mmHg or diastolic blood pressure (DBP) of 80–89 mmHg], and hypertension (SBP ≥140 mmHg or DBP ≥90 mmHg). A participant who self-reported diagnosed hypertension with a physician's prescription of antihypertensive medication and/or any previous diagnosis of hypertension by a health professional was considered hypertensive. In this study, high blood pressure refers to both prehypertension and hypertension.

Biochemical measurements

Blood samples were taken after a 12-h fast to measure blood

Table 1. Sociodemographic, health and lifestyle characteristics of community-dwelling adults in Morocco, STEPS 2017 cross-sectional survey (N=4580)

Characteristics	Total		Men		Women		p*
	n	%	n	%	n	%	
Total	4580	100.0	1604	35.0	2976	65.0	
Sociodemographic							
Age (years)							<0.001
18–29	801	17.5	263	16.4	538	18.1	
30–44	1457	31.8	427	26.6	1030	34.6	
45–59	1316	28.7	465	29.0	851	28.6	
60–69	617	13.5	283	17.6	334	11.2	
≥70	389	8.5	166	10.3	223	7.5	
Residence							0.001
Rural	1818	39.7	689	43.0	1129	37.9	
Urban	2762	60.3	915	57.0	1847	62.1	
Education level							<0.001
No formal education	2392	52.2	624	38.9	1769	59.4	
Primary school	948	20.6	418	26.1	528	17.7	
Middle school	541	11.8	228	14.2	314	10.6	
High school	367	8.0	167	10.4	200	6.7	
University	332	7.2	167	10.4	165	5.5	
Marital status							<0.001
Single	634	13.8	305	19.0	329	11.1	
Married	3363	73.4	1247	77.7	2120	71.2	
Separated/divorced	135	2.9	23	1.4	108	3.6	
Widowed	448	9.8	29	1.8	419	14.1	
Health and lifestyle							
Weight status							0.022
Underweight	199	4.3	69	4.3	130	4.4	
Normal weight	1637	35.7	552	34.4	1085	38.5	
Overweight	1615	35.3	583	36.3	1032	34.7	
Obese	1129	24.7	400	24.9	729	24.5	
Abdominal obesity							<0.001
No	1355	29.8	492	31.1	863	29.1	
Yes	3197	70.2	1092	68.9	2105	70.9	
High blood pressure							0.019
Yes	3523	76.9	1205	75.1	2318	77.9	
No	1057	23.1	399	24.9	658	22.1	
Hyperglycemia							<0.001
Yes	1262	27.6	370	23.1	892	30.0	
No	3318	72.4	1234	76.9	2084	70.0	

Continued

Table 1. Continued

Characteristics	Total		Men		Women		p*
	n	%	n	%	n	%	
Low HDL cholesterol							<0.001
Yes	2620	57.2	850	53.0	1770	59.5	
No	1960	42.8	754	47.0	1206	40.5	
Hypertriglyceridemia							0.117
Yes	753	16.4	249	15.5	504	16.9	
No	3827	83.6	1355	84.5	2472	83.1	
Physical activity levels							<0.001
Active	3588	78.3	1310	81.7	2278	76.5	
Inactive	992	21.7	294	18.3	688	23.5	
Fruit and vegetable intake							0.031
Sufficient	1731	37.8	336	39.7	1095	36.8	
Insufficient	2849	62.2	968	60.3	1881	63.2	
Alcohol consumption							<0.001
No	4348	94.9	1384	86.3	2964	99.6	
Yes	232	5.1	220	113.7	12	0.4	
Smoking status							<0.001
Never	3899	85.1	938	58.5	2961	99.5	
Former	329	7.2	324	20.2	5	0.2	
Current	352	7.7	342	21.3	10	0.3	

*P-value of the association between gender and other variables assessed by the chi-squared test.

glucose, total cholesterol, triglycerides, and HDL cholesterol. These samples were sent to the Reference Laboratory of the Joint Research Unit in Nutrition and Food, Regional Designed Center of Nutrition (AFRA/IAEA), Ibn Tofail University-CNESTEN, Rabat, Morocco. Fasting blood glucose level was interpreted according to the WHO criteria[13] for diagnosing diabetes (≥7 mmol/L or 126 mg/dL) and prediabetes (6.1–6.9 mmol/L or 110–125 mg/dL). In this study, hyperglycemia refers to both prediabetes and diabetes. Based on the European guidelines[14], dyslipidemia was defined as having at least one of the following abnormalities: high total cholesterol (≥5 mmol/L or 190 mg/dL), hyperglyceridemia or high triglycerides (≥1.7 mmol/L or 150 mg/dL), low HDL cholesterol (<1.03 mmol/L or 40 mg/dL for men, <1.29 mmol/L or 50 mg/dL for women), and high LDL cholesterol (≥115 mg/dL or 3.0 mmol/L), calculated using the following formula: LDL cholesterol = total cholesterol – HDL cholesterol – triglycerides /5 (g/L)[14].

Ethical considerations

Ethical approval for this survey was obtained from the Biomedical Research Ethics Committee of the Faculty of Medicine and Pharmacy in Rabat, Morocco (Approval number: 248; Date: 22 March 2016). Before data collection, all invited participants were briefed about the survey objectives and methods, and only those who provided written informed consent were involved. A results sheet was used to inform the participants on-site about the measurement result, and those who were found to be at risk were directed to the closest health center for additional care.

Statistical analysis

The Statistical Package for Social Sciences (SPSS) software (version 27.0.1.0) was used to perform statistical analyses. Results are presented as proportions and 95% confidence intervals using descriptive statistics. The association between categorical variables was examined by the chi-squared test. Bivariate and multivariate logistic regression analyses were conducted to assess the association of current and former smoking with obesity, hyperglycemia, raised blood pressure, hypertriglyceridemia, and low HDL cholesterol. Logistic regression models are reported as crude odds ratio (OR) or adjusted odds ratio (AOR) and 95% confidence interval (95% CI). The AORs were used to control the effect of age, gender, residence, education level, marital status, physical activity level, fruit and vegetable intake, alcohol consumption, weight

status, blood pressure, fasting blood glucose, triglycerides, and HDL cholesterol, as potential confounding variables. A two-tailed p<0.05 was deemed statistically significant.

RESULTS

This study involved 4580 Moroccan adults aged ≥18 years. The characteristics of the study population are shown in Table 1. About two-thirds (65%) of the participants were women, 74% were aged 30–69 years, and 60% lived in urban areas. The prevalence of being overweight, obese, having abdominal obesity, high blood pressure, hyperglycemia, low HDL cholesterol, and hypertriglyceridemia was 35.3%, 24.7%, 76.9%, 27.6%, 57.2%, and 16.4%, respectively. The proportion of individuals who met the WHO recommendations of physical activity and fruit and vegetable intake was 78.3% and 37.8%, respectively. Smoking prevalence was 7.7%. There were significant differences between men and women for all variables, except triglyceride levels.

The proportion of current and former smokers was 7.7% and 7.2%, respectively. There was a significant association of smoking status with sex (p<0.001), age (p=0.001), education level (p<0.001), marital status (p<0.001), weight status (p=0.016), abdominal obesity (p<0.001), hyperglycemia (p<0.001), HDL cholesterol (p=0.002), and triglyceride (p=0.024), as well as physical activity level (p<0.001) and alcohol consumption (p<0.001). Current smoking prevalence increased with age, with the highest rates among individuals aged 30–44 years and 45–59 years compared to their younger and older age groups. However, it decreased as education level increased, with the highest rates among the illiterate and those who completed primary education than those with high level of education. Individuals who were single/married, non-drinkers, and physically active showed a higher prevalence of smoking compared to those who were separated/widowed, alcohol drinkers, and physically inactive. Participants who were urban dwellers and had insufficient fruit/vegetable intake tended to have higher prevalence of smoking than those who were rural dwellers and had sufficient fruit/vegetable intake, respectively, but these differences did not reach statistical significance (Table 2).

The prevalence of overweight/obesity and high blood

Table 2. Smoking status among adults according to demographic, social and behavioral factors in Morocco, STEPS 2017 cross-sectional survey (N=4580)

Variables	Smoking status						p[a]	p[b]
	Never		Former		Current			
	n	%	n	%	n	%		
Total	3899	85.1	329	7.2	352	7.7		
Sociodemographic								
Gender							<0.001	<0.001
Men	938	24.1	324	98.5	342	97.2		
Women	2961	75.9	5	1.5	10	2.8		
Age (years)							0.001	0.001
18–29	732	18.8	19	5.8	50	14.2		
30–44	1281	32.9	54	16.4	122	34.7		
45–59	1066	27.3	134	40.7	116	33.0		
60–69	480	12.3	85	25.8	52	14.8		
>70	340	8.7	37	11.2	12	3.4		
Residence							0.550	0.269
Rural	1532	39.3	141	52.9	145	41.2		
Urban	2367	60.7	188	57.1	207	58.8		
Education level							<0.001	<0.001
No formal education	2133	54.7	164	49.8	96	27.3		
Primary school	740	19.0	79	24.0	127	36.1		
Middle school	446	11.4	36	10.9	60	17.0		
High school	301	7.7	27	8.2	39	11.1		
University	279	7.2	23	7.0	30	8.5		

Continued

Table 2. Continued

Variables	Smoking status						p[a]	p[b]
	Never		Former		Current			
	n	%	n	%	n	%		
Marital status							<0.001	<0.001
Single	534	13.7	32	9.7	68	19.3		
Married	2817	72.2	287	87.2	263	74.7		
Separated/divorced	108	2.8	8	2.4	15	4.3		
Widowed	440	11.3	2	0.6	6	1.7		
Health variables								
Weight status							<0.001	0.016
Non-overweight	1549	39.7	148	45.0	139	39.5		
Overweight/obese	2350	60.3	181	55.0	213	60.5		
Abdominal obesity							<0.001	<0.001
No	1142	29.5	102	31.2	111	31.8		
Yes	2734	70.5	225	68.8	238	68.2		
High blood pressure							<0.001	0.297
Yes	2984	76.5	258	78.4	281	79.8		
No	1057	23.5	-	21.6	-	20.2		
Hyperglycemia							<0.001	<0.001
Yes	1108	28.4	95	28.9	59	16.8		
No	2791	71.6	234	71.1	293	83.2		
Low HDL cholesterol							0.157	0.002
Yes	2247	57.6	159	48.3	214	60.8		
No	1652	42.4	170	51.7	138	39.2		
Hypertriglyceridemia							0.018	0.024
Yes	647	18.6	64	19.5	42	11.9		
No	3252	83.4	265	80.5	310	88.1		
Fruit and vegetable intake							0.728	0.573
Sufficient	1468	37.7	133	40.4	89	25.3		
Insufficient	2431	62.3	196	59.6	263	74.7		
Physical activity levels							0.006	<0.001
Active	3012	77.3	280	85.1	296	84.1		
Inactive	887	22.7	49	14.9	56	15.9		
Alcohol consumption							<0.001	<0.001
No	3862	99.1	223	67.8	263	74.7		
Yes	37	0.9	106	32.2	89	25.3		

a P-value of the association between smoking status (2 categories: smoker and non-smoker) and other variables assessed by the chi-squared test. bP-value of the association between smoking status (3 categories: current, former and never smoker) and other variables assessed by the chi-squared test.

pressure was higher among former and current smokers compared to never smokers. However, the prevalence of hyperglycemia and hypertriglyceridemia was lower in never smokers than former and current smokers (Figure 1).

After adjusting for potential confounding variables, logistic regression analysis showed that both current and former smokers tended to have higher odds of being overweight/obese (AOR=1.08; 95% CI: 0.81–1.64 and AOR=1.22; 95%

Figure 1. Proportion of adults being overweight/obese, having high blood pressure, hyperglycemia or hypertriglyceridemia, according to smoking status, Morocco STEPS 2017 cross-sectional survey (N=4580)

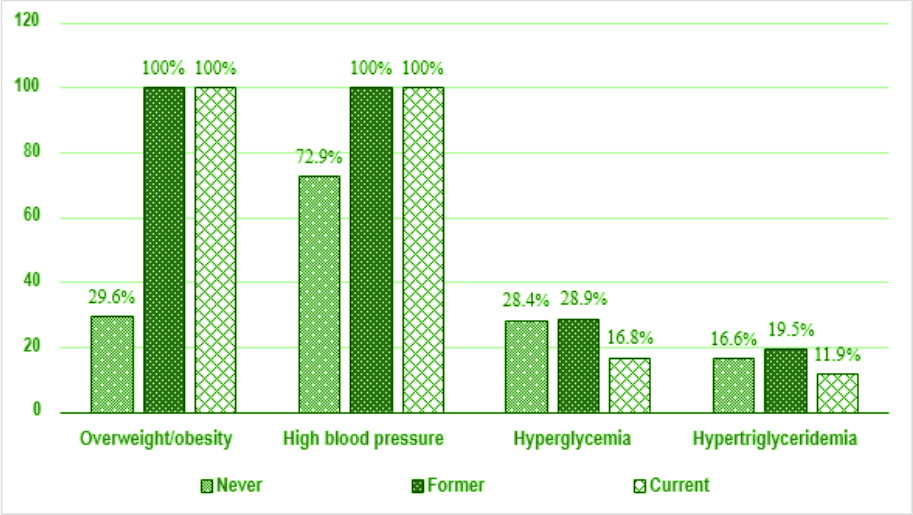

Table 3. Association of being overweight/obese, having high blood pressure, hyperglycemia, low HDL cholesterol, or hypertriglyceridemia, by smoking status in adults, Morocco STEPS 2017 cross-sectional survey (N=4580)

Smoking status	Overweight/obese		High blood pressure		Hyperglycemia		Low HDL cholesterol		Hypertriglyceri-demia	
	OR (95% CI)	AOR (95% CI)	OR (95% CI)	AOR (95% CI)	OR (95% CI)	AOR (95% CI)	OR (95% CI)	AOR (95% CI)	OR (95% CI)	AOR (95% CI)
Never ®	1	1	1	1	1	1	1	1	1	1
Former	1.44 (1.13-1.78)**	1.22 (0.87-1.56)	1.21 (0.90-1.62)	1.15 (0.85-1.61)	0.47 (0.40-0.74)**	0.60 (0.37-0.80)**	1.14 (0.86-1.41)	1.40 (1.13-1.90)**	0.74 (0.45-0.90)*	0.69 (0.46-0.90)*
Current	1.49 (1.09-2.00)*	1.08 (0.81-1.64)	1.13 (0.76-1.60)	1.11 (0.74-1.67)	0.51 (0.28-0.65)**	0.64 (0.42-0.89)*	1.72 (1.17-2.22)**	1.59 (1.19-2.10)**	0.63 (0.35-0.89)**	0.72 (0.39-1.00)*

AOR: adjusted odds ratio; adjusted for age, gender, residence, education level, marital status, physical activity level, fruit and vegetable intake, alcohol consumption, weight status, blood pressure, fasting blood glucose, triglycerides, and HDL cholesterol as confounding variables. ® Reference category. **p<0.01. *p<0.05.

CI: 0.87–1.56, respectively). They also had significantly a higher likelihood of low HDL cholesterol (AOR=1.59; 95% CI: 1.19–2.10, and AOR=1.40; 95% CI: 1.13–1.85, respectively). However, they were significantly less likely than never smokers to have hyperglycemia (AOR=0.64; 95% CI: 0.42–0.89, and AOR=0.60; 95% CI: 0.37–0.80, respectively) and hypertriglyceridemia (AOR=0.72; 95% CI: 0.39–1.00, and AOR=0.69; 95% CI: 0.46–0.90, respectively) (Table 3).

DISCUSSION

This study estimated the prevalence of tobacco smoking and examined its association with various sociodemographic, behavioral, and health factors among adults in Morocco. Overall, 7.7% reported smoking tobacco. Our estimate of current smoking prevalence is lower than what has been reported in other countries. For instance, the current smoking prevalence found in a large study of 11734 participants from 12 European countries was 28.3%[15]. Similar studies also reported a high prevalence of smoking in other European countries such as Kosovo (25.7%)[16], and Georgia (27.1%)[17], as well as in some African countries, including Algeria (21.8%)[18], Libya (21.5%)[19] and South Africa (27.6%)[20].

However, other studies found an approximately comparable prevalence of smoking in large samples of 10703 participants from four Sub-Saharan African countries (10.8%)[21], 4301 adults from Zambia (11.0%)[22] and 2047 participants from Saudi Arabia (12.2%)[23]. In Morocco, Taheri et al.[24] reported a prevalence of tobacco smoking of 15.1% in 2010 and 11.4% in 2023; and Peltzer et al.[25] found that 10.5% of adults were current smokers in 2017. Another study conducted in 2020 among 3883 Moroccan adolescents, showed that 11.1% had already tried smoking cigarettes and 22.2% had at least one smoking parent[26]. Although our findings should be interpreted with caution, since they are based on self-

reported information that may lead to underestimating smoking prevalence, they support the decreasing trend in the prevalence of tobacco smoking in Morocco.

The current study showed that gender, age, education level, marital status, physical activity, and alcohol consumption were significantly associated with smoking status. The prevalence of current smoking was higher in men, and married persons, compared to women and single/separated/widowed persons, respectively. These findings are aligned with previous surveys that have shown a significantly higher prevalence of tobacco smoking in men than in women[17,21] and in married group than in other marital status groups[24]. Unsurprisingly, tobacco use is less common among women than men, given the existing social norms and taboos that discourage women from smoking[27].

The results of this study also showed that the proportion of smokers increases with age with the highest proportion among adults aged 30–44 years and aged 45–59 years, compared to their younger (aged 18–29 years) and older (aged >60 years) counterparts, this is in conformity with previous studies[20,22]. This may be due to the financial stability that enables one to afford tobacco products[28], and to the older adults' self-perceived health that was found to be linked to smoking behavior[29]. It could also be attributed to a lack of specific smoking cessation interventions targeting these sections of the population in Morocco.

Our study not only revealed a significant relationship between education level and tobacco smoking but also found that smoking prevalence decreased as education level increased. This finding aligned with previous research in both industrialized and developing nations[30,31], which suggests that socioeconomic status may impact access to information and interventions designed to reduce smoking. Therefore, smoking control strategies should focus on less educated and poor individuals, as they represent the most vulnerable social groups.

Current smoking prevalence tended to be more common among urban residents compared to rural residents (4.5% vs 3.2%). Although our results are not consistent with some previous studies that reported a higher prevalence of smoking among rural than urban residents[18,22], they align with those of other studies[20,23]. This could be explained by differences in cultural attitudes toward smoking and tobacco control policies and regulations across countries. While some countries have introduced comprehensive tobacco control measures, such as smoking bans in public places and restrictions on advertising, others, like Morocco, consider smoking as socially acceptable. In some communities, the sale of tobacco products and smoking in social settings like cafes and gatherings are even encouraged. On the other hand, in some countries, rural smokers are more likely to access tobacco and other products that are primarily grown in rural areas.

Previous studies have demonstrated a significant association of smoking with alcohol consumption and physical activity[22,32,33]. In contrast, our findings showed a lower prevalence of current smoking among alcohol drinkers and physically inactive individuals compared to non-drinkers and physically active subjects (1.9% vs 5.7% and 1.2% vs 6.5%, respectively). Although additional large-scale and longitudinal studies are needed, our findings highlight the importance of considering alcohol consumption, physical activity, and smoking habits in nutritional counseling and smoking cessation strategies.

The strong link between tobacco smoking and non-communicable diseases, including diabetes mellitus, and dyslipidemia, has been well demonstrated in previous studies[4,34-36]. However, in this study, after adjusting for sociodemographic, behavioral, and other clinical factors, both current and former smokers were significantly less likely to have hyperglycemia or hypertriglyceridemia compared to never smokers. Although our findings are partially consistent with those of some previous studies that showed an inverse relationship between hyperglycemia and smoking[22,25], they should be interpreted with caution. The inverse association of smoking with hypertriglyceridemia and hyperglycemia could be due to behavioral bias as smokers diagnosed with hyperglycemia or hypertriglyceridemia may quit smoking, leading to underrepresentation in the 'current smoker' category. Measurements relying solely on self-reported smoking data without biochemical validation (e.g. cotinine or carbon monoxide levels) may also underestimate the true prevalence of smokers and therefore affect these associations. Also, despite the adjusting for sociodemographic, behavioral and clinical factors, such a reverse association could be related to sample-specific factors that were not explored including socioeconomic status, dietary habits, and stress levels, as well as the presence of residual confounding of various comorbidities. Further studies are required to explore mechanisms underlying the observed associations of smoking with hyperglycemia and hypertriglyceridemia in large community-based surveys that consider biomarkers (e.g. inflammatory markers, insulin levels) and biochemical methods to validate smoking status and improve data accuracy.

Strengths and limitations

The current study has several strengths, including the use of standardized data collection methods based on the WHO STEPwise approach and large sample size, which enable reasonably accurate data on smoking and associated factors. However, there are some limitations to consider. First, due to the cross-sectional nature of the data, causal relationships underlying the reported associations cannot be established, and our findings may not be generalizable to other countries. Second, the relatively low proportion of men in the study population limits the ability to assess gender differences accurately. Third, the presence of residual confounding effects of other variables can result in biased estimates of the association between smoking and targeted health disorders. Fourth, there is a lack of data on biochemical

markers to provide accurate estimates of smoking prevalence rates. Finally, information bias may arise from self-reported demographic and lifestyle factors, particularly smoking and alcohol consumption.

CONCLUSIONS

Smoking was common among the study population and was associated with various sociodemographic, behavioral, and health factors. Both current and former smoking were associated with a higher likelihood of low HDL cholesterol and a reduced likelihood of hyperglycemia or hypertriglyceridemia. Although further larger and longitudinal studies are recommended to better ascertain causal relationships and provide us with deeper insights, our findings underscore the need for effective and well-designed public health interventions to improve smoking cessation and reduce smoking-related comorbidities, particularly among vulnerable groups.

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DATA AVAILABILITY
The data supporting this research are publicly available at the World Health Organization NCD Microdata Repository: https://extranet.who.int/ncdsmicrodata/index.php/catalog/544

AUTHORS' CONTRIBUTIONS
All authors have contributed to the study design, data collection, and the writing, revision, and editing of the manuscript. All authors read and approved the final version of the manuscript.

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