Letter to the Editor

The Association between Waterpipe Smoking and Metabolic Syndrome: A Cross-Sectional Study of the Bushehr Elderly Health Program

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Waterpipe (WP), a less common method of tobacco smoking than cigarette smoking (CS), has become increasingly popular over the last decade. Contrary to popular belief, WP smoking is far from harmless and has multiple health risks similar to, or even exceeding, those seen in CS[1,2]. It has been shown that a WP smoking session lasting about 45 minutes can expose the body to several times as many cardiorespiratory toxins as a CS[1], which further highlights the importance of studying WP. A pooled analysis of national surveys from 2006 to 2009 showed that Bushehr Province, Iran, has the highest prevalence of WP smoking among men (10.0%) and the second-highest among women (14.8%)[3]. Thus, this region is suitable for an evaluation of the chronic impacts of WP smoking on the cardiovascular system.

A few surveys have revealed a correlation between tobacco smoking and metabolic syndrome (MetS); the majority of such investigations have, however, focused on CS and, to all intents and purposes, ignored alternative smoking methods, such as WP smoking. Previous research has documented various adverse effects of WP smoking on cardiometabolic risk factors[2]. Nonetheless, a few studies on WP smoking have yielded unexpected results. A case in point is recent research indicating an inverse correlation between both CS and WP smoking and high blood pressure[4,5]. Such inconsistencies between the results of previous studies, along with the increased popularity of WP smoking, necessitate further study. Accordingly, we aimed to explore the associations between both CS and WP smoking and MetS among elderly subjects in the Iranian province of Bushehr.

This research was designed based on data acquired during the second stage of the Bushehr Elderly Health (BEH) program, a population-based cohort study investigating the risk factors for non-communicable diseases in a representative urban population in Bushehr, Iran. The details pertaining to the study design, sample size calculation, and the methods of clinical and laboratory measurements have been described in detail elsewhere[6]. In brief, 3,000 persons aged 60 years and over with an adequate health status for participation in the program were recruited using a multistage, stratified cluster sampling method. The response rate of the primary study was greater than 90%, showing the representativeness of the sample. Current smoking was considered to mean smoking at least 100 CS in one's lifetime or having smoked WP at least once within the past 30 days preceding the survey, and currently smoking CS or WP every day or some days. Former CS smoking was defined as having smoked at least 100 CS in one's lifetime but currently having quit. Former WP smoking was defined as having a history of WP smoking but currently having quit for at least 30 days preceding the survey. Never-smoking was defined as having smoked less than 100 CS or having reported not having smoked WP in one's lifetime.

MetS was determined in keeping with the revised NCEP-ATP III criteria as the abnormality of

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three or more of the following criteria: (1) high waist circumference (WC): WC ≥ 102 cm in males and ≥ 88 cm in females; (2) high blood pressure (BP): blood pressure ≥ 130/85 mmHg or consumption of anti-hypertensive medications; (3) reduced high-density lipoprotein (HDL)-cholesterol: < 40 mg/dL in males and < 50 mg/dL in females; (4) hyper-triglyceridemia (TG): TG level ≥ 150 mg/dL; (5) hyperglycemia: fasting glucose level of ≥ 100 mg/dL or under treatment for previous diabetes. MetS and its components were described as dependent variables, and smoking status and other risk factors of MetS, such as age, sex, physical activity, BMI, and education, were considered independent variables. This research was approved by the Ethics Committee of the Endocrinology and Metabolism Research Institute of Tehran University. The participants provided written, informed consent. A logistic regression analysis was performed to evaluate the association between smoking status and MetS and its components in different models. Model I showed a univariate correlation with no adjustments, and in models II and III, the confounding factors, including age, sex, BMI, education, and physical activity, were adjusted. In the first step of the logistic regression analysis, the effects of former smoking (CS, WP, or both) and current smoking (CS, WP, or both) on MetS and its components were evaluated with respect to never-smoking. In the next step, the statistically significant results were investigated vis-à-vis their relationships with CS, WP, or both.

Table 1 exhibits the baseline data of the subjects. Of 2,414 subjects enrolled in this study, 1,065 subjects were categorized as never-smokers, 504 as current smokers, and 845 as former smokers. Most of the current smokers were men (540%), whereas women comprised the majority of former smokers (51.4%). Former smokers were significantly older than the other two groups (P = 0.003). Lower values of BMI and hip circumference (HC) were seen in current smokers than in never-smokers ($P \le 0.001$). Former smokers had higher WC, systolic BPs, and mean levels of serum glucose than the never-smokers (P = 0.005, $P \le 0.001$, and $P \le 0.004$, respectively). The serum HDL level was significantly lower among former smokers than never-smokers (P = 0.030). The other baseline laboratory measurements were comparable between the three groups. Regarding adequate physical activity, never-smokers were more active than the other two groups (P = 0.016). Also, the mean education level was higher in never-smokers in comparison with the other two groups ($P < 0.001$).

Table 2 demonstrates the frequency of MetS and its elements according to smoking groups. The prevalence of MetS was 58.0% for the former

Table 1. Demographic and baseline data of the participants according to cigarette and waterpipe smoking status

Variables	Never-smokers (*n* = 1,065)	Current smokers (*n* = 504)	Former smokers (*n* = 845)	Total (*N* = 2,414)	*P* value
Sex (male), *n* (%)	478 (44.9)	272 (54.0)	411 (48.6)	1,161 (48.1)	0.003
Age (years)	68.60 ± 5.94	69.00 ± 6.09	70.46 ± 6.92*	69.33 ± 6.39	< 0.001
Body mass index (kg/m^2)	27.72 ± 4.81	26.38 ± 5.06*	27.93 ± 4.86	27.51 ± 4.91	< 0.001
Waist circumference (cm)	98.42 ± 11.53	96.89 ± 12.55	100.16 ± 12.17*	98.71 ± 12.03	0.005
Hip circumference (cm)	102.91 ± 9.99	100.82 ± 10.22*	103.18 ± 10.27	102.57 ± 10.17	< 0.001
Systolic blood pressure (mmHg)	139.47 ± 19.33	136.60 ± 19.08*	141.62 ± 19.14	139.62 ± 19.29	0.005
Diastolic blood pressure (mmHg)	81.57 ± 8.55	80.79 ± 8.83	81.94 ± 8.71	81.54 ± 8.67	0.218
Fasting plasma glucose (mg/dL)	105.73 ± 41.57	101.58 ± 40.65*	109.56 ± 44.77	106.21 ± 42.61	0.004
Triglyceride (mg/dL)	134.98 ± 70.96	134.44 ± 67.28	138.20 ± 71.91	136.00 ± 70.54	0.525
Total cholesterol (mg/dL)	184.07 ± 45.44	182.71 ± 43.63	179.56 ± 42.89	182.21 ± 44.21	0.070
High-density lipoprotein	46.70 ± 11.52	45.34 ± 11.22	45.38 ± 10.79*	45.95 ± 11.22	0.030
Low-density lipoprotein	110.70 ± 38.99	110.87 ± 37.00	106.96 ± 36.52	109.43 ± 37.75	0.080
Physical activity (+), *n* (%)	273 (25.6)	105 (20.8)	174 (20.6)	552 (22.9)	0.016
Education (years)	6.21 ± 5.21	4.57 ± 4.67*	4.32 ± 4.78*	5.20 ± 5.03	< 0.001

Note. *The mean difference is significant among current smoker or ex-smokers *vs*. never-smokers.

smokers, which was significantly higher than that for current and never-smokers (47.5% and 53.5%, respectively). Furthermore, former smokers had a higher percentage of abdominal obesity, higher FPG, and higher BP than the other two groups (P < 0.05). There was a high percentage of low HDL levels among current smokers as compared with the other two groups, with the difference constituting statistical significance (P = 0.047). The prevalence of high TG levels was comparable among the three groups (P > 0.05).

Table 3 presents the crude and adjusted *OR*s for MetS and its components among current and former smokers. The logistic regression test demonstrated that former smoking was positively and significantly linked to MetS in the fully adjusted model (*OR* = 1.288; 95% *CI*: 1.059 to 1.567). In the subsequent analysis, former WP smoking (*OR* = 1.352; 95% *CI*: 1.060 to 1.725) and former dual smoking (*OR* = 1.848; 95% *CI*: 1.175 to 2.905) had a significant correlation with MetS, whereas former CS showed no significant association with MetS. Similarly, former smoking was significantly associated with higher WC after adjustments were made for confounding factors (*OR* = 1.38; 95% *CI*: 1.10 to 1.73), although this association was seen only in subjects who were dual-smokers of WP and CS (*OR* = 1.828; 95% *CI*: 1.142 to 2.928). No statistically significant correlation was found between current or former smoking and serum TG levels. Former smoking was inversely related to high FPG levels (*OR* = 0.689; 95% *CI*: 0.545 to 0.870); however, no such association was found for any of the former smoking sub-groups in the subsequent analysis. Current smoking was significantly linked to low levels of HDL-C, for which current WP smokers had higher odds in the subsequent analysis (*OR* = 1.472; 95% *CI*: 1.134 to 1.910). Current WP smoking was also inversely linked to hypertension (*OR* = 0.544; 95% *CI*: 0.413 to 0.716).

In this research, we evaluated the correlation of CS and WP smoking, whether done at present or in the past, with MetS and its components in an elderly population. Having made adjustments for potential confounders, such as age, sex, and BMI, we observed that subjects who quit WP smoking or dual WP smoking and CS were more likely to have MetS. Moreover, former WP smokers had a significantly higher likelihood of abdominal obesity than never-smokers. We also detected a direct link between current WP smoking and low HDL-C levels and a negative correlation with hypertension. Interestingly, we found no association between pure CS and MetS and/or its components.

Recent years have witnessed an increase in attention to research on the relationship between WP smoking and MetS. A cross-sectional study by Shafique et al.[2] revealed a three-fold rise in the likelihood of MetS among current WP smokers compared with never-smokers. In contrast, in our study, MetS was more prevalent among former smokers than current and never-smokers. Among former smokers, i.e., those who reported WP smoking or dual smoking of WP and CS had a significantly higher likelihood of MetS. Also, a recent population-based study by Soflaei et al.[7] showed that former smokers and current WP smokers had a higher likelihood of MetS compared with never-smokers. The result of the study by Soflaei and colleagues with respect to former smokers is in accordance with ours, albeit they failed to determine whether or not these effects were related to WP or CS.

The effect of WP smoking on abdominal obesity has been evaluated in several prior studies. To our knowledge, nearly all of these studies have found a positive association between current WP smoking and obesity[2,7]. The prevalence of obesity among former smokers has been assessed independently in only a single study[7], which reported no significant

Table 2. Frequency of cardiometabolic risk factors according to smoking categories

Variables	Smoking groups				*P* value
	Never-smokers	Current smokers	Former-smokers	Total	
Metabolic syndrome, *n* (%)	569 (53.5)	239 (47.5)	490 (58.0)	1,298 (53.8)	0.001
High Waist circumference, *n* (%)	621 (58.3)	258 (51.2)	515 (60.9)	1,394 (57.7)	0.002
High Triglyceride, *n* (%)	327 (30.7)	165 (32.8)	275 (32.5)	767 (31.8)	0.595
Low High-density lipoprotein cholesterol, *n* (%)	492 (46.2)	265 (52.7)	419 (49.6)	1,176 (48.7)	0.047
High Fasting plasma glucose, *n* (%)	461 (43.3)	183 (36.4)	399 (47.2)	1,043 (43.2)	0.001
High Blood pressure, *n* (%)	797 (74.8)	318 (63.1)	647 (76.7)	1,762 (73.0)	< 0.001

association as compared with never-smokers. In our study, abdominal obesity was more prevalent in former smokers, and we found a significant link between the cessation of both WP smoking and CS and abdominal obesity. It should be mentioned that most previous studies have evaluated adolescences

Table 3. Adjusted *OR*s of metabolic syndrome and its components according to smoking status

Variables	Never smokers	Current smokers	Former smokers	Current WP (CW) (*n* = 289) or Former WP (FW) (*n* = 484) smokers	Current CS (CC) (*n* = 144) or Former CS (FC) (*n* = 180) smokers	Former Dual Users (*n* = 91)
Metabolic Syndrome				FW: 1.352 (1.060–1.725)*	FC: 0.948 (0.670–1.340)	1.848 (1.175–2.905)*
Model 1	Ref	0.788 (0.637–0.974)*	1.201 (1.001–1.441)*			
Model 2	Ref	0.873 (0.698–1.091)	1.352 (1.115–1.640)*			
Model 3	Ref	0.821 (0.654–1.030)	1.288 (1.059 –1.567)*			
High WC				FW: 1.161 (0.870–1.549)	FC: 1.386 (0.966–1.990)	1.828 (1.142–2.928)*
Model 1	Ref	0.750 (0.606–0.928)*	1.116 (0.928–1.342)			
Model 2	Ref	0.895 (0.692–1.157)	1.414 (1.131–1.768)*			
Model 3	Ref	0.867 (0.668–1.125)	1.384 (1.104–1.735)*			
High Triglyceride				–	–	–
Model 1	Ref	1.102 (0.878–1.383)	1.089 (0.897–1.322)			
Model 2	Ref	1.144 (0.910–1.439)	1.166 (0.958–1.421)			
Model 3	Ref	1.162 (0.919–1.471)	1.098 (0.897–1.343)			
Low HDL-C				CW: 1.472 (1.134–1.910)*	CC: 1.138 (0.795–1.629)	–
Model 1	Ref	1.297 (1.049–1.604)*	1.145 (0.956–1.373)			
Model 2	Ref	1.404 (1.130–1.744)*	1.212 (1.007–1.459)*			
Model 3	Ref	1.381 (1.106–1.724)*	1.147 (0.950–1.383)			
High FPG				FW: 1.148 (0.910–1.447)	FC: 0.950 (0.674–1.338)	1.305 (0.832–2.046)
Model 1	Ref	0.855 (0.713–1.025)	0.639 (0.510–0.802)*			
Model 2	Ref	0.813 (0.676– 978)*	0.630 (0.501–0.791)*			
Model 3	Ref	0.889 (0.736–1.075)	0.689 (0.545–0.870)*			
High BP				CW: 0.544 (0.413–716)*	CS: 1.006 (0.681–1.487)	–
Model 1	Ref	0.575 (0.458–0.722)*	1.014 (0.894–1.364)			
Model 2	Ref	0.578 (0.459-0.727)*	1.058 (0.855–1.310)			
Model 3	Ref	0.603 (0.475-0.767)*	0.957 (0.767–1.194)			

Note. Model 1: Univariate analysis; Model 2: Adjusted for age and sex; and Model 3: age, sex, BMI, education (y), and physical activity In high WC and Mets, BMI is not included in the models. *Refers to the significant values in all smoking categories. WP, Waterpipe; CS, Cigarette smoking; HDL-C, High-density lipoprotein cholesterol; FPG, Fasting plasma glucose; BP, Blood pressure.

and adults and have failed to include the elderly population. Hence, the present inconsistency between our study and previous studies may be partly due to the specific characteristics of the different populations recruited for the investigations. In other words, it is probable that some former smokers were forced to quit smoking because of concurrent comorbidities, such as MetS, abdominal obesity, and a high estimated risk of cardiovascular disease.

High TG levels and low HDL levels are two other components of MetS, whose associations with WP smoking have been examined in some prior studies. Shafique et al.[2] demonstrated a positive, significant correlation between current WP smoking and high TG levels but no significant association with low HDL levels. In contrast to their study, our results demonstrated a nearly 1.5-times higher likelihood of low HDL levels among current WP smokers, whereas there was no significant association between WP smoking and TG. The Soflaei et al.[7] study is concordant with our study in that they showed that current WP smokers had significantly lower levels of HDL and nonsignificant differences in serum TG levels compared to never-smokers.

Hyperglycemia is another component of MetS that has been shown to be significantly and positively associated with current WP smoking in some studies[2,7]; nonetheless, Soflaei et al. scintillatingly detected a negative association between CS and DM[7]. Our results showed that high FPG levels were less prevalent among current smokers than never-smokers. Be that as it may, our subsequent analysis of the smoking sub-groups showed no independent association between WP or CS and high FPG levels.

In our results, the effects of current WP smoking on BP were contrary to expectations insofar as that we found an inverse association with an *OR* of 0.54 for hypertension. Whereas some studies have demonstrated the incremental effects of smoking on BP[8], other studies have found an inverse[4] correlation between these factors. Despite the uncertainty regarding the exact mechanism of this reverse association, some assumptions have been posited previously. For example, Onat et al.[9] argued that the protective effect of smoking on hypertension was confounded by a low weight among smokers as compared with never-smokers. We showed that this inverse association remained significant even after adjusting for BMI. In addition, there is evidence that the clearance of nicotine following abstinence from smoking, even in the short term, can result in neurohormonal withdrawal-induced hypotension[4]. Some studies have demonstrated that smokers have lower levels of psychological stress when smoking[10], which may partly explain the hypotensive effects of active smoking.

The principal strength of this research is our focus on a homogeneous group of elderly subjects. On the other hand, our research suffers from certain limitations that are worthy of note. First, the classification of subjects as never-, current-, and former- smokers was self-reported rather than evaluated by quantitative methods, such as the measurement of serum cotinine levels. Second, our study has some information gaps, including the time elapsed since quitting and the duration of smoking, which should be considered in future studies. Ultimately, due to the cross-sectional design of this research, the causality of the associations cannot be easily established.

Overall, regardless of some slight discordance with the literature, our results demonstrated that former WP smokers had enhanced odds of developing MetS and abdominal obesity. Current WP smokers had an elevated risk of low HDL levels and a reduced risk of hypertension. Notwithstanding the hypotensive effect of WP smoking, as demonstrated in our study and some others, it is important that WP smoking be avoided due to its known role in increasing cardiovascular disease and mortality. Further research is needed to clarify not only the various discrepancies seen among previous studies but also the mechanisms of these associations.

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