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BRIEF REPORT

CO Exposure and Puff Topography Are Associated With Lebanese Waterpipe Dependence Scale Score

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ABSTRACT

Introduction: Waterpipe tobacco smoking involves self-administration of the dependence-producing drug nicotine. Few studies have examined if dependence in waterpipe smokers influences toxicant exposure and smoking behavior.

Method: Current waterpipe tobacco smokers were categorized based on Lebanese Waterpipe Dependence Scale-11 (LWDS-11) score (LWDS-11: LOW < 7; $N = 59$; HIGH > 13; $N = 59$). Participants abstained from smoking for 12 hr and then completed a single 30-min waterpipe tobacco smoking episode. Expired-air carbon monoxide (CO) was measured before and 5 min after smoking and puff topography was measured during smoking.

Results: Total mean smoking time was 30.9 min ($SD = 3.5$) and did not differ significantly by LWDS-11 score. CO boost was greater for participants in the HIGH versus LOW groups (62.3 vs. 43.6 ppm, $p < .01$). Similarly, those in the HIGH versus LOW group took more puffs (198.6 vs. 157.1 puffs, $p < .01$), longer duration puffs (2.7 vs. 2.3 s, $p < .05$), puffs with lower flow rate (10.3 vs. 12.6 L/min, $p < .01$), and less time between puffs (8.0 vs. 12.4 s, $p < .001$).

Conclusion: The puff topography of waterpipe tobacco smokers can be predicted by LWDS-11 score, with those scoring higher taking longer duration and lower velocity puffs at a higher frequency. These behavioral differences may underlie the 40% greater CO exposure observed for those with higher LWDS-11 scores. To the extent that waterpipe dependence is associated with more smoke inhalation, more dependent smokers will be exposed to greater amounts of toxic smoke constituents.

INTRODUCTION

Like other forms of tobacco use, tobacco smoking using a waterpipe (hookah, narghile, shisha) involves self-administration of nicotine, a psychomotor stimulant that supports dependence (Blank et al., 2011; Eissenberg & Shihadeh, 2009; Neergaard, Singh, Job, & Montgomery, 2007). Some waterpipe tobacco smokers display classic dependence indicators, including failed quit attempts (Ward et al., 2005) and abstinence-induced symptoms (Rastam et al., 2011). These indicators of dependence are supported by qualitative work, with reports such as: "I like to dominate everything, but the narghile [waterpipe] has completely dominated me. That bothers me. My happiness is related to the narghile. It is essential for having a good time" (Hammal, Mock, Ward, Eissenberg, & Maziak, 2008, p. 4).

The Lebanese Waterpipe Dependence Scale-11 (LWDS-11; Salameh, Waked, & Aoun, 2008) was developed to study waterpipe dependence in Arabic-speaking populations. Scores on this 11-item measure are correlated significantly with nicotine exposure (as measured by saliva cotinine), carbon monoxide (CO) exposure, and waterpipe use frequency (Salameh et al., 2008). In cigarette smokers, tobacco/nicotine dependence is associated with detailed measures of smoking behavior or "puff topography" (e.g., puff number, volume, interpuff interval [IPI]) such that greater puff number and puff volume, for example, are observed in more dependent smokers (Zielińska-Danch et al., 2010). These results have clear implications for understanding links between dependence and other cigarette-caused disease because larger volumes of smoke translate into greater exposure to smoke toxicants.

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Waterpipe tobacco smoking also involves exposure to smoke toxicants (Jacob et al., 2011), and this study was designed to examine the extent to which waterpipe dependence level, as indexed by the LWDS-11, is related to puff topography in waterpipe tobacco smokers. It also allows an examination of the relationship between LWDS-11 scores and CO exposure and smoker's gender. We hypothesized that waterpipe smokers who scored higher on the LWDS-11 would be exposed to more CO and would take more and larger puffs.

METHODS

Human Participant Issues, Recruitment, and Screening

This laboratory study was approved by the Institutional Review Boards of Virginia Commonwealth University and Jordan University of Science and Technology (JUST). Participants were recruited into the study, which was conducted at JUST, by advertisement and word of mouth. Each participant provided written informed consent.

Screening consisted of an interview that included medical history, demographic information, tobacco use history, and the LWDS-11 (consent, interview, and LWDS-11 were all conducted in Arabic). Healthy individuals who reported using a waterpipe at least 2 times per month for the past 6 months and whose responses on the LWDS-11 where either <7 (LOW group), out of a maximum score of 33, or >13 (HIGH group) were recruited to complete a single laboratory session that involved smoking tobacco from a waterpipe following a 12-hr tobacco abstinence period. The 2 times/month for the past 6 months criterion was chosen to ensure that we would be likely to include waterpipe tobacco smokers across a wide range of dependence levels. The LOW and HIGH designations were chosen arbitrarily but were based on a sample of 188 waterpipe smokers with a median score of 10 for whom "mild" smokers ($N = 99$) had a mean score of 7.3 and "heavy" smokers ($N = 52$) had a mean score of 14.9 (Salameh et al., 2008). Abstinence was objectively verified with an expired-air CO concentration of either <10 ppm or half the screening CO level. In addition to excluding participants whose LWDS-11 scores were between 8 and 12, we excluded individuals with self-reported history of chronic disease or psychiatric conditions, history of or active cardiovascular disease, low or high blood pressure, seizures, and regular use of prescription medication (other than vitamins or birth control), as well as women who were pregnant or breast feeding. Also excluded were individuals who report smoking cigarettes regularly (i.e., >5 cigarettes/month for this study) or regular use of any other tobacco product.

Procedure

In the experimental session and once abstinence was verified, participants were provided with a waterpipe (15 cm diameter, 61 cm height, 750 ml water volume, with a leather hose), quick lighting charcoal disks, aluminum foil, and their preferred brand and flavor of "ma'assel" tobacco. Participants were invited to load 10 g of tobacco and otherwise prepare the waterpipe themselves and to smoke it *ad libitum*. The smoking session lasted for at least 30 min (as in Rastam et al., 2011), though participants were invited to smoke as long after the 30-min period as they liked. Puff topography parameters were measured continuously during the smoking session using a portable topography unit attached to the waterpipe hose (Shihadeh and Saleh, 2005). Briefly, a calibrated differential pressure obstruction flow sensor was integrated into a waterpipe hose and inhalation-induced pressure changes automatically were converted to voltage signals, amplified, digitized, and sampled. Postprocessing software converted digital signals to air flow (ml/s) and integrated these data to produce measures of puff volume, duration, number, flow rate, and IPI. In addition, exactly 5 min after the last puff, expired CO was assessed via breath CO monitor (Vitalagraph, Lenaxa, KS). Expired-air CO is highly correlated with carboxyhemoglobin level (Wald, Idle, Boreham, & Bailey, 1981) and is a commonly used measure of tobacco smoke exposure (Eissenberg & Shihadeh, 2009; Jacob et al., 2011; Salameh et al., 2008). In every session, the waterpipe hose was tipped with a new, sterile, disposable mouthpiece for participant protection. All participants were compensated the Jordanian equivalent of $20 for their time and any cost due to their enrollment in the study.

Analysis

Data were analyzed with IBM Statistics SPSS version 21 and Stata 12.0. For the variables with continuous outcomes, ANOVA was used with two between-subject factors: LWDS-11 group (LOW or HIGH) and gender (man or woman). For the two dichotomous outcomes (ever-smoked cigarettes and owns a waterpipe), the method used was logistic regression, with LWDS-11 group, gender, and an interaction term between LWDS-11 group and gender as independent variables. $p < .05$ was considered significant.

RESULTS

Three hundred forty individuals agreed to participate and were screened for inclusion to attain the target sample size of 32 men and 32 women in each of the two dependence groups. All of the participants invited into the laboratory session completed it, but human or computer error led to 10 incomplete datasets. Thus, all analyses were conducted using the complete datasets from the 59 LOW (28 men) and the 59 HIGH (27 men) participants. Table 1 provides demographic statistics for these participants, all of whom described their ethnicity as "Arab."

The mean age of the sample was 23.6 years ($SD = 5.5$). On average, participants in the LOW group were younger than those in the HIGH group (21.9 vs. 25.2 years, $p < .01$) and women were younger than men (22.6 vs. 24.7 years, $p < .05$); no significant interaction for age was observed. There were no significant differences across group or gender for BMI and ever cigarette use (Table 1). There was a significant difference by group for LWDS score (LOW = 6.0 vs. HIGH = 18.2, $p < .001$). This difference was expected because of the method of group determination. For weekly waterpipe use, there was a significant interaction between gender and LWDS-11 score, with men and women in the LOW group reporting a mean of 2.1 uses/week ($SD = 1.4$ for men and 1.5 for women), but men in the HIGH group reporting a mean of 5.6 uses/week ($SD = 1.9$) compared with a mean of 2.8 uses/week for women ($SD = 2.1$).

Table 1. Statistical Analysis Results for Demographic and Outcome Measures

	Sex		Dependence		Sex × Dependence		LWDS-11 group, mean (*SD*)		Gender, mean (*SD*)	
	F^a	*p* value	F^a	*p* value	F^a	*p* value	Low (*N* = 59)	High (*N* = 59)	Men (*N* = 55)	Women (*N* = 63)
Demographic measure										
Age (years)	5.1	<.05	12.5	<.01	1.3	*ns*	21.9 (3.9)	25.2 (6.3)	24.7 (6.3)	22.6 (4.4)
BMI	1.4	*ns*	2	*ns*	<1	*ns*	22.9 (3.5)	23.8 (3.9)	23.8 (3.7)	23.0 (3.7)
Ever cigarette use[b]	1.3 (0.4, 3.9)	*ns*	0.9 (0.3, 2.7)	*ns*	1.3 (0.3, 6.0)	*ns*	0.69 (0.46)	0.69 (0.46)	0.65 (0.48)	0.73 (0.45)
LWDS score	<1	*ns*	523.6	<.001	<1	*ns*	6.0 (1.3)	18.2 (3.9)	11.9 (7.2)	12.3 (6.4)
Owns a waterpipe[b]	0.2 (0.02, 1.5)	*ns*	0.05 (0.006, 0.43)	<.001	5.5 (0.50, 61.2)	*ns*	0.56 (0.50)	0.88 (0.33)	0.76 (0.43)	0.68 (0.47)
Heads/waterpipe session	1.6	*ns*	5.2	<.05	1.1	*ns*	1.3 (0.5)	1.6 (1.0)	1.6 (1.0)	1.4 (0.6)
Waterpipe use (days/week)	10.6	<.01	56.4	<.001	30.6	<.01	2.1 (1.4)	4.4 (2.2)	3.8 (2.4)	2.8 (1.9)
Outcome measure										
CO boost (ppm)	3.8	<.06	7.3	<.01	<1	*ns*	43.6 (30.0)	62.3 (44.4)	60.0 (39.6)	46.8 (37.4)
Puff number	<1	*ns*	7.4	<.01	<1	*ns*	157.1 (69.9)	198.6 (91.4)	175.5 (68.9)	179.8 (95.2)
Puff duration	3.3	<.07	4.4	<.05	1.3	*ns*	2.3 (0.9)	2.7 (1.1)	2.7 (1.1)	2.4 (0.9)
Mean flow rate (L/min)	4.2	<0.05	11.3	<.01	2.6	*ns*	12.6 (4.4)	10.3 (3.2)	12.3 (4.6)	10.8 (3.4)
Interpuff interval (s)	<1	*ns*	16.3	<.001	<1	*ns*	12.4 (7.4)	8.0 (3.9)	10.1 (6.9)	10.2 (5.7)
Mean puff volume (L)	6.6	<.05	<1	*ns*	<1	*ns*	0.52 (0.28)	0.48 (0.24)	0.57 (0.28)	0.44 (0.23)
Total volume	4.7	<.05	<1	*ns*	1.2	*ns*	82.6 (55.1)	91.8 (52.6)	98.5 (55.0)	77.3 (51.3)
Smoke time (min)	<1	*ns*	2.7	*ns*	1.4	*ns*	31.4 (4.1)	30.4 (2.5)	31.1 (4.4)	30.7 (2.4)

Notes. LWDS = Lebanese Waterpipe Dependence Scale; *ns* = nonsignificant.
[a] $df = (1,114)$.
[b] Because the variables "ever cigarette use" and "owns a waterpipe" are dichotomous, the method of analysis used was logistic regression. In these cases, *OR* with 95% CI are presented instead of *F*-statistics in the initial columns. Similarly, proportions are presented instead of means in the later columns.

CO boost was greater for participants in the HIGH versus LOW groups (62.3 vs. 43.6 ppm) with a trend toward a significant main effect of gender (Table 1). A significant main effect of group (and no significant effect of gender and no interaction) was observed for puff number (LOW mean = 157.1 puffs, *SD* = 69.9; HIGH mean = 198.6 puffs, *SD* = 91.4), puff duration (LOW mean = 2.3 s, *SD* = 0.9; HIGH mean = 2.7 s, *SD* = 1.1), mean flow rate (LOW = 12.6 L/min, *SD* = 4.4; HIGH = 10.3 L/min, *SD* = 3.2), and IPI (LOW = 12.4 s, *SD* = 7.4; HIGH = 8.0 s, *SD* = 3.9). A significant main effect of gender (but not dependence level and no significant interaction) was observed for mean puff volume (mean for men = 0.57 L, *SD* = 0.28; mean for women = 0.44 L, *SD* = 0.23) and total volume (mean for men = 98.5, *SD* = 55.0; mean for women = 77.3, *SD* = 51.3). There were no significant main effects and no interaction observed for total smoking time, which was almost exactly 30 min for all participants on average (overall mean = 30.9 min, *SD* = 3.5).

DISCUSSION

With this study, we demonstrate for the first time that dependence level in waterpipe users, as assessed by the LWDS-11, is associated positively with CO exposure and smoking behavior, with individuals who scored higher on the LWDS-11 producing greater mean expired-air CO concentration and taking more and longer puffs when they smoked. Waterpipe tobacco smoke contains nicotine, CO, and a variety of other toxicants, such as volatile aldehydes that contribute to pulmonary disease (Al Rashidi et al., 2008; Shihadeh et al., 2012) and polycyclic aromatic hydrocarbons that cause cancer (Shihadeh & Saleh, 2005). In addition, carcinogenic tobacco-specific nitrosamines are almost certainly in waterpipe tobacco smoke, as they can be found in waterpipe tobacco smokers (Jacob et al., 2011; Radwan, Hecht, Carmella, & Loffredo, 2013). The observation that smokers with higher LWDS-11 scores are exposed to more CO suggests that these individuals may inhale more smoke and thus be at greater risk for waterpipe-induced cardiovascular and pulmonary disease as well as cancer (Akl et al., 2010; Alsatari, Azab, Khabour, Alzoubi, & Sadiq, 2012; Hakim et al., 2011; Khabour, Alsatari, Azab, Alzoubi, & Sadiq, 2010; Khabour et al., 2012; Raad et al., 2011; Shaikh, Vijayaraghavan, Sulaiman, Kazi, & Shafi, 2008). This risk may be even greater for men who are dependent on waterpipe, as they are exposed to more CO and inhaled more smoke per waterpipe use session. Thus, dependent smokers, who smoke more frequently, may be exposed to disproportionately higher CO, and, very likely, other toxicants.

In this study, participants with higher LWDS-11 scores drew puffs at lower flow rates. We speculate that this may be a learned behavior that stems from the fact that waterpipe hoses are porous, and that higher flow rates demand greater suction pressure. As a result, higher flow rates result in greater quantities of fresh air being drawn through the hose walls, resulting in lower CO and nicotine smoke concentrations (Saleh & Shihadeh, 2008). Thus, puffing harder on a waterpipe hose results in diminishing returns to the smoker, potentially explaining why dependent (and presumably more experienced) users tend to take longer puffs of lower flow rate than less dependent users.

Limitations of the study include its convenience sample and the laboratory setting that may have influenced smoking behavior, particularly because eating and drinking that typically accompany waterpipe tobacco smoking were prohibited in this study. An additional limitation of this study is that it was conducted in a single country, Jordan. Waterpipe tobacco smoking is becoming popular globally and is quite common in many countries where Arabic is not the primary language (Jackson and Aveyard, 2008; Pärna, Usin, & Ringmets, 2008; Poyrazoğlu, Sarli, Gencer, & Günay, 2010; Primack et al., 2013). Because the LWDS-11 was developed in Arabic, if the potential public health threat of this method of tobacco use is to be understood and addressed globally (Maziak, 2008), theoretically based and psychometrically sound waterpipe-specific dependence measures in other languages must be developed (Fagerström & Eissenberg, 2012).

Despite these limitations, our findings suggest that waterpipe tobacco users who score higher on the LWDS-11 take in greater amounts of CO compared with those users who score lower on this measure of waterpipe dependence. Furthermore, those who score higher take more puffs, lower velocity puffs, and less time between puffs. These behavioral differences may underlie the greater CO exposure observed for those with higher LWDS-11 scores.

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DECLARATION OF INTERESTS

None declared.

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