

Original investigation

Concurrent Alcohol Use and Waterpipe Tobacco Smoking: Smoking Topography, Toxicant Exposure, and Abuse Liability

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Abstract

Introduction: Relative to non-waterpipe (WP) smokers, WP smokers are more than twice as likely to use alcohol and frequently consume alcohol before or during smoking sessions. Co-use of alcohol and WP may result in greater toxicant exposure compared to WP smoking alone. To date, no study systematically has investigated the impact of acute alcohol intoxication on WP smoking topography, exposure to tobacco-related toxicants, or abuse liability.

Methods: Dyads of current WP smokers and drinkers (N = 42; age = 21–32 years) completed two in-laboratory ad libitum smoking sessions (≤2 hours) following 12-hour nicotine abstinence in a double-blind, randomized crossover design in which they consumed a placebo versus active drink (sustained breath alcohol concentration = .08). Exhaled carbon monoxide (eCO) and plasma nicotine concentration were assessed. Questionnaires assessed smoking experience and smoking urge. Smoking topography was measured continuously throughout each smoking session.

Results: The alcohol session was associated with increased inhaled volume, flow rate, and WP session duration compared to placebo. Compared to placebo, participants reported a more positive overall smoking experience following the alcohol session and greater smoking urges pre- and post-smoking session. Although both sessions resulted in significant increases in eCO and plasma nicotine, no significant differences emerged in eCO or nicotine exposure between the active and placebo sessions.

Conclusions: Co-use of alcohol and WP may contribute to the maintenance of WP smoking through enhanced smoking experiences, increased urge to smoke, and significant exposure to addictive nicotine. Regulations may be necessary to limit the sale of alcohol in WP smoking lounges and reduce exposure to secondhand smoke.

Implications: The findings suggest co-use of alcohol and WP tobacco likely maintain WP use and dependence by enhancing the smoking experience and increasing urges to smoke. These findings

have implications for regulations aimed at limiting co-use of alcohol and WP tobacco in WP lounges and limiting exposure to secondhand smoke.

Clinical trials registration: NCT03096860

Introduction

Although use of traditional tobacco products in the United States (cigarettes, cigars, etc.) continue to decline, rates of waterpipe (WP) tobacco smoking remain high.¹ WP tobacco smoking involves heating flavored tobacco via charcoal placed on top of the tobacco, separated by perforated aluminum foil. The user inhales through a hose, causing air to be pulled over the charcoal, heating the tobacco, which produces smoke that then passes through a water bowl and hose and into the mouth and lungs. WP smokers are exposed to many of the same toxicants that are present in combustible cigarette smoke, such as heavy metals, benzene, polycyclic aromatic hydrocarbons, tar, carbon monoxide, and nicotine, but often at higher levels.²⁻⁴ As such, WP smoking is associated with many of the same negative health outcomes as combustible cigarette use such as cancer, lung disease, respiratory illness, and cardiovascular disease.^{2,5,6}

The co-occurrence of alcohol use and WP smoking is quite common among adults^{7,8} and young adults.⁹⁻¹¹ Compared to non-WP smokers, WP smokers are more than twice as likely to use alcohol.¹¹ Participants in qualitative research note that alcohol use makes it easier to start smoking WP due to decreased inhibition.¹² They also report that WP and alcohol use are complementary and the co-use of the two results in enhanced physical effects. Furthermore, WP smokers frequently consume alcohol immediately before or during a WP smoking session.¹³ An uncontrolled field study⁷ found that increased alcohol consumption was associated with greater smoke exposure even after controlling for other factors that would be expected to contribute to smoke exposure (eg, number of bowls smoked, number of charcoals used, and number of people in the smoking group), suggesting alcohol use may confer unique risk for greater toxicant exposure.

Although little research has examined the impact of acute alcohol intoxication on WP tobacco smoking patterns and exposure to nicotine- and tobacco-related toxicants, research investigating the interaction of cigarette smoking and alcohol consumption can be used to understand the co-use of alcohol and nicotine. Laboratory-based trials indicate that cigarette smokers smoke more cigarettes after consuming alcohol and have a more difficult time abstaining from smoking due to greater urges to smoke, resulting in more exposure to nicotine- and tobacco-related toxicants.^{14,15} Studies using ecological momentary assessment indicate that cigarette smokers experience greater smoking urges after drinking^{16,17} and smoking lapses often occur during drinking episodes.¹⁸ However, because of the unique features of WP tobacco smoking, direct comparisons cannot be made. As such, investigation of the effects of alcohol consumption on WP tobacco smoking is warranted.

This study examines the effect of acute alcohol intoxication on subjective smoking experience, urges for WP smoking, WP smoking topography, and resultant nicotine and carbon monoxide exposure in a randomized placebo-controlled crossover-design laboratory study. We hypothesized that compared to placebo, alcohol consumption would be associated with (1) a more positive overall smoking experience including a greater willingness and interest in experiencing the session again, (2) greater urges for WP smoking, (3) increased smoking topography (ie, increased total inhaled volume,

total smoke and puff time, puff duration, flow rate, number of puffs, and maximum puff volume and decreased inter-puff interval), and (4) increased nicotine and CO exposure.

Methods

Sample

Participants were 42 current WP smokers (21 dyads) who regularly consumed alcohol. Participants were recruited via flyers at WP lounges, word of mouth, and from an existing participant pool from February to August 2017. Consistent with previous WP smoking research,¹⁹ participants met the following criteria: (1) smoke WP at least three times over the last 6 months, (2) be at least 21 years, (3) speak and understand English, (4) deny current serious chronic health issues such as asthma, cystic fibrosis, chronic obstructive pulmonary disease, heart disease, (5) not currently be pregnant or breast-feeding or have plans to become pregnant or begin breast-feeding at any point during the study, (6) deny past month illicit drug use, excluding cannabis, and (7) identify an eligible partner with whom to complete study procedures. In addition, participants needed to (1) typically consume at least 1 and at least 2 drinks per episode for women and men, respectively, (2) drink alcohol at least 1 time per week, and (3) not currently be seeking alcohol treatment. Only dyads in which both members met inclusion criteria were eligible to participate. Prior to completion of study procedures, participants completed written informed consent. All study procedures were approved by the university's Institutional Review Board. All outcome measures, study conditions, and data exclusions for the experiment are included in this manuscript.

Procedures

This study was a double-blind, placebo-controlled, randomized crossover design. Participants completed two laboratory visits and were assigned randomly to visit order. Given the social nature of WP smoking,^{20,21} participants completed WP smoking in self-identified dyads. Dyads were most often composed of friends or romantic partners and were not required to be same sex. Each member of the dyad smoked from their own WP and were prohibited from smoking the other dyad member's WP to ensure accurate puff topography measurement. In one session, both participants in the dyad were administered a placebo drink (0 g/kg alcohol) and in the other, both were administered an active drink (0.8 g/kg alcohol) to minimize conversational comparisons regarding subjective experience which could compromise participant blinding. A minimum 48-hour washout period was required between sessions to mitigate the impact of order and carryover effects. Participants were required to be 12 and 24 hours abstinent from tobacco and nicotine and alcohol, respectively. Pre-session abstinence from alcohol and tobacco and nicotine was biochemically verified at the beginning of each visit by breath alcohol concentration (BrAC) = 0.000 and exhaled carbon monoxide (eCO) less than 10 ppm. Pregnancy exclusion was verified via urine pregnancy test at the beginning of each visit for female participants. All participants were instructed to eat a normal lunch but to not eat for 2 hours prior to arrival to

the laboratory and were provided a standardized meal of pretzels and water prior to beverage administration.

Sessions took place in a laboratory under negative pressure. Alcohol administration was based on participant sex, height, and weight to achieve a dose of 0.8 g/kg.¹⁴ Drink administration was based on accepted procedures.^{22,23} Participants remained seated for the entirety of each study visit to decrease awareness of interoceptive signals of intoxication.²⁴

On completion of beverage administration and absorption, participants were allowed to smoke WP ad libitum for up to 2 hours but were allowed to discontinue smoking at any time. Throughout the smoking session, WP puff topography was measured via a pressure flow sensor integrated into the hose.²⁵ To ensure participants remained at an approximate BrAC of 0.8 g/kg, booster drink administration was conducted when participants' BrACs dropped to 0.050–0.065. If this occurred, beverage administration procedures were repeated to dose the participant back to approximately 0.8 g/kg. Participants chose their preferred WP tobacco from a selection of 10 flavors and flavors were held constant across sessions for each participant. BrAC was measured immediately following a standard absorption period, every 15 minutes during the smoking session, and until the conclusion of the study visit (see Figure 1 for mean BrACs during sessions). Participants were compensated for their time and participation at the end of each study visit (total compensation = \$270).

Participants were discouraged from eating, drinking, or using their cell phone during the session. All study staff that had contact with participants were blind to the alcohol content of the beverages. Blinded research assistants made drinks and administered but did not view BrAC measurements. One research assistant was unblinded to condition and readied drink recipes and recorded BrAC measurements.

WP materials

Waterpipe

For standardization, the same brand and model of WP was used throughout the study (Mya Francesco, single hose) and all aspects of the WP apparatus were held constant. *Charcoal*: One quick light charcoal briquette was used initially. However, participants were allowed additional charcoals if requested. *Tobacco*: Participants chose their preferred WP tobacco from a selection of 10 Al Fakher flavors. The WP tobacco flavor was held constant across sessions for each participant. All WP tobacco offered had approximately equivalent nicotine contents, verified by independent analysis. Participants

started the session with one bowl packed with 10 g of WP tobacco. Participants were allowed an additional bowl packed with 10 g of WP tobacco if requested. *Aluminum foil*: Bowls packed with WP tobacco were covered with aluminum foil with prepunched holes for consistency.

All WP materials used (WP apparatus, charcoal brand, tobacco flavor, bowl, and foil brand) were consistent across sessions for each participant.

Measures

Sociodemographics

A self-report questionnaire was used to assess participants' age, sex, marital status, ethnicity, employment status, household income, and education.

WP Smoking and Alcohol Use History and Dependence

At baseline, current WP smoking frequency was assessed by a single item, "Which statement best describes your hookah smoking during the past month?"²⁶ Response options were the following: "I did not smoke hookah in the past month," "I smoked less than once a week," and "I smoked at least once a day or on most days." WP smoking quantity was measured by the item, "On average, how many hookahs/heads/bowls do you usually smoke per month?"²⁶ The Lebanon Waterpipe Dependence Scale-11 (LWDS-11²⁷), an 11-item self-report measure of nicotine dependence specifically relating to WP smoking, was used to measure WP dependence. LWDS-11 total scores greater than 10 are indicative of WP dependence.²² Typical quantity of alcohol use was assessed by asking participants how many alcoholic drinks they consume on each day of the week during a typical month. The seven items were summed to create a total drinks per week score. The presence of a potential alcohol use disorder and alcohol-related problems was assessed by the Alcohol Use Disorder Identification Test (AUDIT²⁸). Scores greater than seven are indicative of harmful or hazardous alcohol use. The LWDS-11 and AUDIT are reliable and valid measures of WP dependence and alcohol use problems, respectively.

Other Tobacco/Nicotine Product Use

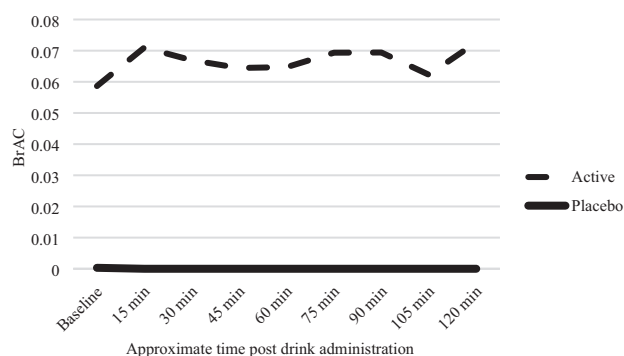
Participants reported use of other tobacco and nicotine products including electronic cigarettes (all styles and generations), combustible cigarettes, cigars (including Cubans, cigarillos, and little cigars), smokeless tobacco, and snus. If participants reported ever using the product, a single item was used to assess current use ("Have you used [product] in the past 30 days?").

Tobacco-Related Toxicants

eCO levels were measured using a Bedfont Smokerlyzer (Upchurch, UK: Bedfont Scientific Ltd.) immediately prior to and 5 minutes following the completion of each WP smoking session. Blood samples were collected just before the onset of smoking and immediately after the smoking session (within 5 minutes of the last puff) for analysis of plasma nicotine concentration. Samples were analyzed according to standardized methods.²⁹ eCO and nicotine boost from pre- to post-session were calculated by subtracting the pre- from post-session measure. Greater eCO and nicotine boost is indicative of greater toxicant exposure.

WP Puff Topography

Puff topography was measured throughout the WP smoking session via a pressure flow sensor integrated into the hose²⁵ to produce



Note. BrAC = Breath alcohol concentration.

Figure 1. Mean breath alcohol concentration during Sessions. BrAC = breath alcohol concentration.

measures of total smoke and puff time, puff duration, flow rate, interpuff interval, number of puffs, total inhaled volume, and maximum puff volume.

Subjective Smoking Experience

At the conclusion of each smoking session, participants completed measures of subjective experience during the recently completed session (adapted from Leavens et al.³⁰). Items were assessed on a visual analog scale from 0 to 100. Items included “How pleasant would the session you just experienced be to experience again right now?” and “How much of a desire or urge do you have to experience the session you just experienced again right now, just for the pleasure of smoking?” Similar items assessed need to experience the session again, wanting, liking, enjoyment, pleasure, satisfaction, interest in experiencing the session again, and willingness to experience the session again. Each item was analyzed separately.

WP Smoking Urge

Smoking urge was assessed using a WP-adapted version of the Questionnaire of Smoking Urges-Brief (QSU-Brief³¹). The QSU was adapted by replacing “cigarette” and “smoking” with “hookah” and “smoking hookah.” The QSU is a 10-item, validated measure of smoking urge and craving. QSU-Brief items are measured on a 0 (*strongly disagree*) to 6 (*strongly agree*) scale. Items are summed to create a total scale score with greater scores indicating greater smoking urge. WP smoking urge was assessed following drink administration but prior to smoking and again following the smoking session at each visit.

Subjective Intoxication

Participants completed a measure of subjective intoxication (“How intoxicated from alcohol do you feel right now?”) throughout the smoking session at both visits. Subjective intoxication was measured at every BrAC measurement (every 15 minutes). Participants responded on a visual analog scale from 0 to 100. Average subjective intoxication was calculated by averaging across all measures of subjective intoxication for each visit.

Data Analysis

Overall, 194 participants were assessed for eligibility. Of those, 88 were eligible, 46 completed one visit, and 44 completed both visits. However, two participants (1 dyad) were removed from analyses because of illness (not due to alcohol poisoning; BrAC < .08), resulting in a final sample size of 42 participants. The data were screened for carryover and order effects. Order was assessed using analysis of variances to compare means for all outcome measures for each session type (placebo and active beverage) by order (placebo first or second; alcohol first or second). Carryover effects were tested by isolating session type (alcohol or placebo) and assessing differences in means for the first versus second session. The absence of significant differences indicated no order or carryover effects. Means and standard deviations were calculated for all outcome measures. For plasma nicotine concentration, observed values below the level of quantification were assumed to be half the level of quantification (0.5 ng/mL). Owing to the pilot nature of this study, differences between the active alcohol and placebo sessions in terms of subjective experience items, measures of WP puff topography, and toxicant exposure were investigated using paired samples *t* tests ($p < .05$). To test the impact of subjective intoxication on outcomes, analyses were

rerun using one-way analyses of covariance, with average subjective intoxication as a covariate. All analyses were conducted using SPSS version 24 (IBM, Armonk, NY). For one participant, two measures (ie, average puff duration and average flow rate) of WP topography from a smoking session were missing due to device malfunction. For another two participants, eCO measures were missing due to device malfunction. Two participants were missing data on smoking urges questions and were excluded from analyses. Finally, nine participants were missing plasma nicotine data for pre- and/or post-alcohol session and eight were missing plasma nicotine data for pre- and/or post-alcohol session. Missing plasma nicotine data were due to participant refusal or inability to collect the sample.

Results

Participant Demographics

Complete sample characteristics are presented in Table 1. Participants were 25.2 (SD = 3.1) years old and the majority were male ($n = 24$, 57.1%). The majority identified as white/Caucasian ($n = 31$, 73.8%), reported being single ($n = 28$, 66.7%), and having less than a college degree ($n = 24$, 57.2%). The majority of participants reported smoking tobacco from a WP less than once per week ($n = 26$, 61.9%) and smoking 6.73 (SD = 13.5) bowls per month. Overall, the participants were low dependent smokers ($M_{LWDS-11} = 6.3$, SD = 3.9). On average, participants reported consuming 8.8 (SD = 5.3) drinks per week and were overall high-risk drinkers ($M_{AUDIT} = 7.5$, SD = 3.9). In terms of other current tobacco, electronic cigarettes were the most commonly used product ($n = 15$, 35.7%), followed by cigarettes ($n = 12$, 28.6%) and cigars ($n = 8$, 19.1%).

Subjective Smoking Experience

Following the active alcohol session, participants reported a greater desire or urge [$M_{alcohol} = 40.4$, SD = 28.7, $M_{placebo} = 24.8$, SD = 24.4, $t(41) = 3.2$, $p = .003$] and need [$M_{alcohol} = 17.2$, SD = 22.3, $M_{placebo} = 9.00$, SD = 16.1, $t(40) = 2.9$, $p = .006$] to continue the session compared to the placebo session. In regard to other subjective smoking experience items, no significant differences were found between the active and placebo sessions (Figure 2).

WP Smoking Urge

Following drink administration but prior to WP smoking session, participants reported greater smoking urges after active alcohol administration ($M_{alcohol} = 29.8$, SD = 12.1) compared to placebo drink administration [$M_{placebo} = 26.8$, SD = 12.7, $t(39) = 2.1$, $p = .042$]. Similarly, participants reported greater smoking urges post-smoking session during the active alcohol session ($M_{alcohol} = 16.0$, SD = 7.8) compared to the placebo session [$M_{placebo} = 13.3$, SD = 4.1, $t(41) = 2.8$, $p = .007$].

WP Puff Topography

Participants chose to continue smoking longer during the active alcohol session ($M_{alcohol} = 94.7$ minutes, SD = 29.3) compared to the placebo session [$M_{placebo} = 83.4$ minutes, SD = 31.4, $t(41) = 4.0$, $p < .001$]. Similarly, participants inhaled a greater total volume of smoke during the alcohol session ($M_{alcohol} = 89.6$ L, SD = 59.7) compared to the placebo session [$M_{placebo} = 69.9$ L, SD = 58.6, $t(41) = 2.1$, $p = .039$]. During the alcohol session, 14 participants smoked the full 2 hours and during the placebo session, 13 participants smoked the full 2 hours ($p = .815$). Average flow rate was also greater during

Table 1. Sample Characteristics

Variable	M/N	SD/%
Age	25.2	3.1
Sex (male)	24	57.1
Ethnicity		
White/Caucasian	31	73.8
Asian	7	19.7
Hispanic/Latino	2	4.8
Arab	2	4.8
American Indian/Alaska Native	1	2.4
Marital status		
Single, never married	28	66.7
Married	6	14.3
Other	8	19.0
Education		
High school diploma	6	14.3
Some college/technical school	12	28.6
Associate's degree	6	14.3
Bachelor's degree	14	33.3
Some postgraduate school	1	2.4
Master's degree	3	7.1
Employment status		
Full-time	24	57.1
Part-time	7	16.7
Unemployed	2	4.8
Student	9	21.4
Household income		
0–9999	6	14.3
10 000–19 999	5	11.9
20 000–29 999	3	7.1
30 000–39 999	4	9.5
40 000–49 999	8	19.0
50 000–59 999	4	9.5
60 000–69 999	3	7.1
70 000–79 999	1	2.4
≥80 000	8	19.0
WP smoking frequency		
At least once/day or most days	4	9.5
At least once/week, but not daily	6	14.3
Less than once/week	26	61.9
No past month WP smoking	6	14.3
Bowls smoked per month	6.7	13.5
LWDS-11	6.3	3.9
Other product use—current		
Electronic cigarettes	15	35.7
Cigarette	12	28.6
Cigars	8	19.1
Average drinks per week	8.8	5.3
AUDIT score	7.5	3.9

AUDIT = Alcohol Use Disorder Identification Test; LWDS-11 = Lebanon Waterpipe Dependence Scale-11; WP = waterpipe.

the alcohol ($M_{\text{alcohol}} = 13.3$ L/min, $SD = 4.1$) compared to the placebo session [$M_{\text{placebo}} = 11.9$ L/min, $SD = 4.5$, $t(40) = 2.2$, $p = .032$]. The other topography measures, such as puff duration and volume were not significantly different between the two sessions (see Table 2).

Toxicant Exposure

During the active alcohol session, plasma nicotine concentration increased from 0.5 ($SD = 0.0$) to 13.4 ng/mL ($SD = 9.4$), $t(32) = 8.1$, $p < .001$. Similarly, during the placebo session, plasma nicotine concentration increased from 0.6 ($SD = 0.3$) to 14.0 ng/mL

($SD = 12.3$), $t(33) = 6.2$, $p < .001$. However, no significant differences in overall nicotine boost were present between the active and placebo sessions [$M_{\text{alcohol}} = 13.7$, $SD = 9.7$, $M_{\text{placebo}} = 13.3$, $SD = 12.5$, $t(30) = 0.2$, $p = .857$].

eCO increased from 1.6 ($SD = 3.4$) to 38.7 ppm ($SD = 28.4$) during the active alcohol session [$t(39) = 8.3$, $p < .001$] and from 1.6 ($SD = 3.5$) to 34.6 ($SD = 26.8$) ppm during the placebo session [$t(39) = 8.2$, $p < .001$]. However, no significant differences emerged in eCO boost between the active alcohol and placebo sessions [$M_{\text{alcohol}} = 37.1$ ppm, $SD = 28.4$, $M_{\text{placebo}} = 33.0$ ppm, $SD = 25.6$, $t(39) = 0.9$, $p = .366$].

Subjective Intoxication

Including subjective intoxication as a covariate in the analyses resulted in two measures of subjective smoking experience [urge/desire ($p = .136$) and need ($p = .249$)], smoking urge following drink administration ($p = .632$) and post-smoking session ($p = .066$), and average flow rate ($p = .488$) no longer remaining significant. However, although not significant in initial analyses, number of puffs and total puff time were significant after including subjective intoxication in the model such that participants took a greater number of puffs [$M_{\text{alcohol}} = 157.56$, $SD = 106.79$, $M_{\text{placebo}} = 133.74$, $SD = 115.68$, $F(1,78) = 4.59$, $p = .035$] and spent a greater total amount of time puffing [$M_{\text{alcohol}} = 6.79$, $SD = 4.09$, $M_{\text{placebo}} = 5.62$, $SD = 3.40$, $F(1,78) = 11.31$, $p = .001$] when consuming the active drink compared to the placebo drink.

Discussion

This study is the first to examine systematically the impact of acute alcohol consumption on WP tobacco smoking topography, subjective smoking experience, smoking urges, and toxicant exposure. Consistent with previous studies, during each session participants inhaled large amounts of smoke (79.7 L), resulting in significant levels of acute exposure to CO (36.6 ppm) and nicotine (13.7 ng/mL).^{2,3} Yet, when consuming alcohol, participants reported a more positive overall experience and greater urges for WP smoking at pre- and post-session. When drinking alcohol, participants inhaled a greater volume of smoke by engaging in a longer smoking session and exhibiting greater average flow rate compared to the placebo session. Moreover, many of the effects were robust to the inclusion of subjective intoxication as a covariate. These findings suggest that alcohol may increase the abuse potential of WP and it may also increase users' exposure to harmful tobacco-related toxicants known to cause cancer, periodontal and cardiovascular disease because of the greater volume of smoke inhaled.

Unlike a previous uncontrolled study conducted at WP lounges,⁷ which found that patron BrAC was positively associated with eCO and mediated by length of the smoking session, alcohol consumption and resultant differences in session length and puff topography in the present study did not translate into significant differences in eCO exposure between sessions. A potential reason for this discrepancy is that the current study was conducted in a highly controlled setting and in rooms under constant and substantial negative pressure (up to 35 Pa), whereas the previous study was conducted in a WP lounge under normal ventilation. These differences in ventilation may have resulted in differential exposures to secondhand smoke, with greater exposure under normal ventilation and therefore higher eCO levels. In the WP lounge study, time spent in the lounge mediated the relationship between increased BrAC and eCO.

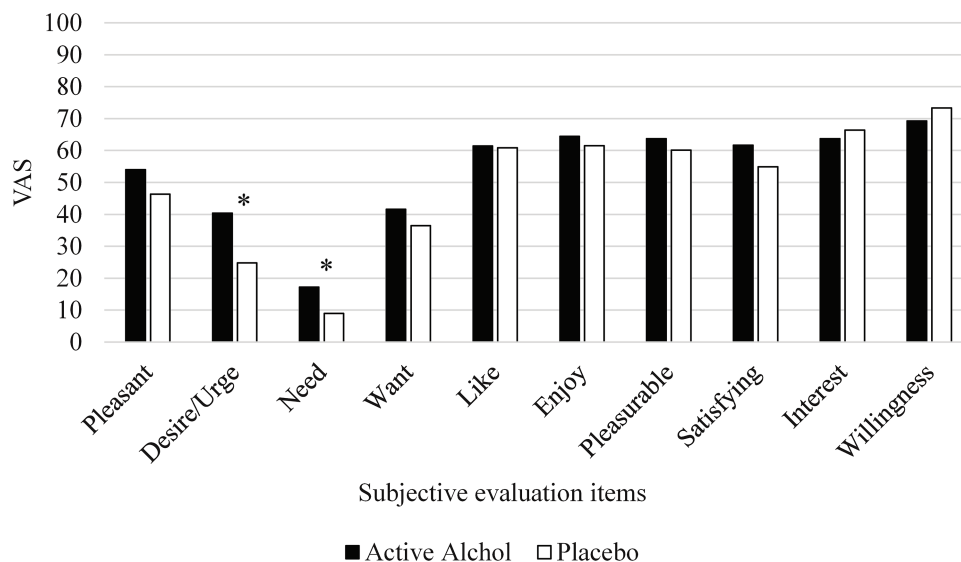


Figure 2. Subjective smoking experience by session VAS = visual analog scale. **p*<.01.

Table 2. WP PuffTopography by Session

	Active Alcohol		Placebo		df	t	p
	Mean	SD	Mean	SD			
Total smoke time, min	94.67	29.26	83.43	31.36	41	4.01	<.001
Cumulative puffing time, min	9.51	19.01	5.62	3.40	41	1.39	.174
Average puff duration, s ^a	3.00	1.14	3.02	1.25	40	0.14	.888
Average flow rate, L/min ^a	13.25	4.14	11.88	4.50	40	2.22	.032
Average interpuff interval, s	45.20	24.73	48.20	28.92	41	1.08	.287
Total number of puffs	152.19	104.86	133.74	115.68	41	1.18	.244
Total inhaled volume, L	89.55	59.65	69.92	58.61	41	2.13	.039
Average puff volume, L	0.69	0.39	0.64	0.43	41	1.04	.303
Maximum puff volume, L	1.77	0.77	1.80	1.09	41	0.25	.803

^aone participant missing data for this measure due to device malfunction.

Similarly, in the current study, active alcohol use was associated with longer smoking sessions, suggesting that had the study been conducted under normal ventilation, differences in eCO may have emerged and could have been similarly explained by the duration of smoking session. Taken together, these findings have important implications, suggesting that the implementation and enforcement of existing state-specific regulations aimed at reducing secondhand smoke exposure in WP lounges, such as requiring appropriate ventilation and that WP lounges are housed in standalone buildings rather than strip malls, would significantly reduce patron’s exposure to harmful tobacco-related toxicants.

The alcohol session was associated with greater desire/urge and need for the session compared to the placebo session. This finding suggests that consumption of alcohol before and during WP smoking may maintain WP smoking and contribute to the development or maintenance of WP dependence. Although not tested in the current study, alcohol use may result in greater smoking urges by way of learned associations between alcohol consumption and WP tobacco smoking via repeated past pairings of the substances. Compared to the placebo session, alcohol consumption resulted in a greater urge to smoke both pre- and post-smoking session, indicating participants would likely lapse more quickly when consuming alcohol

and may help explain why participants chose to continue smoking longer when consuming alcohol versus placebo. Future research might explore experimentally whether, in a lapse task,¹² WP smokers lapse more quickly after consuming an alcohol versus placebo drink. Consistent with the cigarette literature, the current results replicate findings that alcohol and tobacco potentiate the effects of one another.^{15,18,32} However, the current study is one of the first to replicate this phenomenon with WP tobacco.

In conjunction with past research, the current findings have implications for WP smoking interventions.^{12,13} When providing WP smoking interventions, co-use of alcohol should be assessed. If the patient is not interested in or is unwilling to quit WP smoking, they should be provided education related to the negative impact of alcohol use on WP tobacco smoking and toxicant exposure. Specifically, providers should inform WP smokers who also use alcohol that co-use of these substances is related to changes in smoking patterns that could result in greater exposure to WP-related toxicants. In addition, for WP smokers that are unwilling to quit, providers may suggest limiting the duration of WP smoking sessions when consuming alcohol given that participants chose to engage in a significantly longer smoking session when consuming alcohol compared to placebo in this study. The longer duration of WP

smoking likely accounts for the differences in total inhaled volume between the alcohol and placebo sessions and may result in greater exposure to WP-related toxicants if smoking in a setting with normal ventilation, such as a friend's home.

Despite the novel and significant findings, this study is not without limitations. The design was highly controlled to isolate the effects of alcohol consumption; however, research conducted at WP lounges has displayed similar patterns of results and also found alcohol consumption was associated with increased session duration, providing support for the generalizability of these findings. Future research should monitor WP puff topography unobtrusively³³ and gather nicotine and eCO measures in WP lounges. The present study did not incorporate a condition in which no drinks were served. This condition would mimic more closely a real-world setting and could be expected to produce a similar pattern of results as the current study but with amplified effects because of the lack of control for alcohol expectancies. The current study did not incorporate a placebo tobacco. Doing so would allow for the isolation of effects directly related to alcohol consumption versus nicotine exposure. This study assumed nonindependence among participants because the study was not powered for more sophisticated analyses. Future research incorporating dyads should use data analytic analyses that correct for dyadic interdependence. Finally, participants in the current study were majority male and White; therefore, the present findings may not generalize to more diverse samples.

The current research contributes to our understanding of the impact of concurrent alcohol use and WP smoking, two substances often used together. The findings provide evidence suggesting concurrent alcohol use and WP smoking exacerbate each other's effects and increase users' need and desire for the product, likely contributing to the maintenance of use and WP dependence. Even when incorporating a placebo alcohol condition, changes in smoking topography occurred and would likely be amplified if a no drink condition were incorporated. Future research is needed to understand this proposed effect more fully.

Funding

EL was supported by the National Institute on Drug Abuse (NIDA; F31 DA04252) and the Oklahoma Tobacco Settlement Endowment Trust (092-016-0002). TE and AS were supported by the National Institute on Drug Abuse of the National Institutes of Health (NIH) under Award Number P50DA036105 and the Center for Tobacco Products of the US Food and Drug Administration. NIH/NIDA had no role in study design, data collection, analysis, or interpretation, manuscript preparation, or the decision to submit the paper for publication. The content is solely the responsibility of the authors and does not necessarily represent the views of the NIH or the FDA.

Declaration of Interests

TE and AS are paid consultants in litigation against the tobacco industry and are named on a patent application for a device that measures the puffing behavior of electronic cigarette users.

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