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Smoking topography and abstinence in adult female smokers

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Abstract

Preliminary evidence, within both adults and adolescents, suggests that the intensity with which cigarettes are smoked (i.e. smoking topography) is predictive of success during a cessation attempt. These reports have also shown topography to be superior compared to other variables, such as cigarettes per day, in the prediction of abstinence. The possibility that gender may influence this predictive relationship has not been evaluated, but may be clinically useful in tailoring gender-specific interventions. Within the context of a clinical trial for smoking cessation among women, adult daily smokers completed a laboratory session that included a 1-hour ad-libitum smoking period in which measures of topography were collected (N=135). Participants were then randomized to active medication (nicotine patch vs. varenicline) and abstinence was monitored for 4 weeks. Among all smoking topography measures and all abstinence outcomes, a moderate association was found between longer puff duration and greater puff volume and continued smoking during the active 4-week treatment phase, but only within the nicotine patch group. Based on the weak topography-abstinence relationship among female smokers found in the current study, future studies should focus on explicit gender comparisons to examine if these associations are specific to or more robust in male smokers.

Keywords

Tobacco; smoking topography; gender; women; smoking cessation; abstinence

1. Introduction

Long-term abstinence remains difficult to attain for the vast majority of smokers, with successful cessation prevalence ranging from 4–7% (CDC, 2011; Cohen et al., 1989; Hughes, 2003). Women seem to have poorer smoking cessation outcomes compared to men during both unassisted and medication-assisted quit attempts (Bohadana, Nilsson, Rasmussen & Martinet, 2003; Fortmann & Killen, 1994; Husten et al., 1997; Perkins, 2001; Perkins & Scott, 2008; Scharf & Shiffman, 2004; Wetter et al., 1999), though results supporting those findings have been mixed in population-based studies (Jarvis, Cohen, Delvevo & Giovino, 2012). This apparent difference among male and female smokers

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suggests a need for studies to explore how the variables maintaining smoking differ across men and women, which may lead to more efficacious gender-based interventions.

The literature is replete with predictors of abstinence, including socioeconomic status, nicotine dependence, age, time to first cigarette, gender, etc. (Foulds et al., 2006; Harris et al., 2004; Hymowitz et al., 1997; Jardin & Carpenter, 2012; Nides et al., 1995), all shown to be associated with quitting with moderate consistency and reliability. Some research has focused on smoking topography (e.g., puff volume, duration, etc.), and its relation to clinical outcomes. Smoking topography is an appealing potential predictor as it may be more consistent, objective, and reliable compared to self-report predictors of abstinence, and provides measures of smoking reinforcement and reward (Perkins, Karelitz, Giedgowd & Conklin, 2012). One study of adult smokers showed that those participants with less intense puffing characteristics were more likely to achieve abstinence (Strasser, Pickworth, Patterson & Lerman, 2004), which has been replicated among adolescent smokers (Franken, Pickworth, Epstein & Moolchan, 2006). In both studies, topography was a robust predictor of abstinence whereas other variables, such as cigarettes per day and nicotine dependence, were not. This suggests that smoking topography may be a more useful predictor of abstinence compared to self-report measures.

No studies to this point have assessed the influence of gender on the predictive relationship between smoking topography and cessation outcomes. There are several reasons why this exploration is warranted. Women have been shown to have less intense topography characteristics (i.e. smaller and shorter puffs) compared to men (Eissenberg, Adams, Riggins & Likeness, 1999; Melikian et al., 2007; Perkins et al., 2012), are less sensitive to the subjective effects of nicotine (Perkins et al., 2009), but may have enhanced sensitivity to nicotine when estradiol levels are elevated (Lynch & Sofuoglu, 2010). A recent study from our research group has shown that lower levels of progesterone in relation to estradiol were associated with more intense topography (Schiller et al., 2012), suggesting that puffing patterns may vary across the menstrual cycle. Smoking among men and women may also be differentially maintained; such that men smoke primarily for pharmacologic reinforcement of nicotine, whereas women may be driven more by non-nicotine smoking stimuli, such as smoking cues (Perkins, 1996; Perkins, Donny & Caggiula, 1999; Perkins, Jacobs, Sanders & Caggiula, 2002). Taken together, these findings suggest that women do not experience the physiological effects of smoking as intensely as men, which may therefore influence their puffing characteristics. Given evidence that women have less intense topography, and yet may have more difficulty quitting, it is reasonable to hypothesize that a topography-abstinence relationship may be weak in female smokers, if present at all. Failure to demonstrate this relationship in female smokers would provide additional support for non-nicotine variables maintaining smoking and help inform treatment efforts. The purpose of the current report was to assess the association between topography and abstinence among female smokers.

2. Materials and Methods

2.1 Participants

The current study was part of a parent trial that assessed the influence of ovarian hormones on smoking cessation (results forthcoming). Eligible participants were female smokers (≥10 cigarettes per day) between the ages of 18–45 years, who had regular menstrual cycles, and were not taking hormonal contraceptives. Participants were allowed to enter the study at any time during their menstrual cycle phase. All procedures were approved by the university Institutional Review Board.

2.2 Procedures

2.2.1. Smoking topography assessment—Topography data for this secondary analysis were available for 135 participants (of 140 participants in the parent trial). Approximately 1–2 weeks following screening, participants returned to the laboratory to complete a cue reactivity session and a 1-hour ad-libitum smoking period in which topography data were collected. Participants could smoke as many cigarettes of their preferred brand as they wished during this 1-hour period. The laboratory session was preceded by 12 hours of smoking deprivation, confirmed by breath carbon monoxide (CO). Given the short half-life of CO (4-hr half-life; SRNT, 2002), this measure provided the most appropriate quantitative verification of brief periods of abstinence. Smoking topography measures were collected via the CReSS Pocket (Borgwaldt KC, Inc.), and included: number of puffs, mean and total puff volume (ml), mean puff duration (msec), flow rate (ml/sec), and peak flow rate (ml/sec). Based on self-report diaries, 39% of participants were in the luteal phase and 49% were in the follicular phase (12% of participants had missing phase data) during the laboratory session.

2.2.2. Treatment & follow-up—Immediately following the laboratory session, participants were randomized (double blind) to receive active medication of either varenicline (VAR) or transdermal nicotine patches (TNP). The target quit date was set for 1 week following the laboratory session. Participants returned to the clinic on their target quit day and received either active or placebo TNP, with ongoing VAR/placebo tablets. The treatment phase lasted for a total of 4 weeks to allow for the measurement of ovarian hormone levels throughout the entire menstrual cycle, regardless of phase at enrollment. Even though treatment was shorter than clinical guidelines recommend, 4 weeks provided sufficient time to collect abstinence outcomes in order to draw conclusions regarding the relationship between ovarian hormones and smoking cessation. Participants completed five study visits during the treatment phase to provide confirmation of smoking status through CO and self-report. One follow-up visit occurred one month post-treatment (Week 8).

2.3 Statistical analyses

Abstinence endpoints were calculated as the last week, two weeks, and four weeks of treatment, as well as 7-day point prevalence abstinence (PPA) at the follow-up visit. Standard descriptive statistics were used to summarize demographic and smoking characteristics. Smoking outcomes were subjected to multivariable risk regression with robust error variance estimates to determine adjusted relative risk ratios. Abstinence outcomes were determined from the intent-to-treat sample. To further assess the effect of treatment assignment, modifying effects were assessed through interaction effects and stratified models. Initial models were adjusted for primary treatment assignment (VAR vs. TNP) and secondary models were additionally adjusted for independent predictors of abstinence (i.e. age, living with another smoker, Fagerström Test for Nicotine Dependence (FTND) score, and the number of cigarettes smoked during the ad-lib period). Covariates were independently and jointly entered into the models and assessed for significance and modifying effects. Significant covariates were retained on an individual model basis. Analyses were performed using SAS v9.3. The type I error rate was controlled at 0.05 for all analysis.

3. Results

Participants averaged 32 years of age, were mostly Caucasian, and smoked an average of 16 cigarettes per day (Table 1). During the 1-hour ad-lib period, participants smoked an average of 3 cigarettes and took approximately 12 puffs from each cigarette. Treatment groups (VAR vs. TNP) generally did not vary on demographic and smoking characteristics, though

TNP participants had longer puff duration on the first cigarette smoked during the ad-lib period as well as for all cigarettes, and greater puff volume for all cigarettes compared to VAR participants.

Initial and adjusted models determining risk ratios of smoking versus abstinence, adjusted for treatment assignment, showed that all topography measures were unassociated with smoking status at all time points (Table 2). Given no significant associations and slightly more intense topography in the TNP group (prior to randomization), the modifying effects of treatment assignment were explored, though this study was not sufficiently powered to detect modifying effects of treatment. During the 4 weeks of active treatment, a significant association was found between greater total puff volume on the first cigarette (RR=2.95 (1.49–5.82); p=0.002) and all cigarettes smoked (RR=3.14 (1.05–9.39); p=0.041) among participants randomized to the TNP condition. This relationship was also demonstrated for longer puff duration on the first cigarette (RR=2.45 (1.14–5.27); p=0.022) and all cigarettes (RR=2.70 (1.26–5.79); p=0.011). Participants who received VAR showed no significant associations between topography measures and abstinence.

4. Discussion

Across a broad range of smoking topography measures, and several abstinence outcomes in a sample of adult female smokers, we found limited evidence of a predictive relationship between lab-based topography assessments and abstinence. More evidence of a topography-abstinence relationship in participants randomized to TNP was found. Participants receiving TNP with more intense topography characteristics had poorer treatment outcomes when abstinence was assessed during 4 weeks of active treatment. These results suggest that the relationship between topography and abstinence was possibly modified and masked by treatment with VAR, but not TNP. No associations between topography and abstinence were found when treatment groups were collapsed. These findings are consistent with the notion that smoking behavior of women is maintained by more behavioral and cue-specific, rather than pharmacological influences (Perkins, 1996; Perkins et al., 1999; Perkins et al., 2002). Though the current study cannot directly assess the influence of gender given an all-female sample, our results suggest that smoking topography among women may not be a robust predictor of abstinence, and may depend on ovarian hormone levels at the time of topography assessment. While ovarian hormone levels were not analyzed in the current report, a previous study showed that ratios of ovarian hormones were associated with differential topography (Schiller et al., 2012). Therefore, smoking topography may be more dynamic in women and fluctuate throughout the menstrual cycle, thus potentially obscuring a topography-abstinence relationship if phase is not controlled for during the smoking assessment.

Smoking topography still holds the potential to be clinically relevant with respect to tailored smoking cessation interventions. Franken et al. (2006) and Strasser et al. (2004) showed that topography predicted abstinence, while cigarettes per day and nicotine dependence did not, suggesting that topography may go above and beyond self-reported intake measures of current smoking. Given high rates of relapse to smoking and the substantial healthcare and lost productivity costs due to smoking-related illnesses, promising predictors of relapse (even among sub-populations of smokers) should be aggressively pursued and incorporated into research and clinical practice to maximize successful outcomes. To further support the clinical utility of topography assessments, Perkins et al. (2012) showed reliability of topography measures across multiple laboratory sessions in both men and women (menstrual cycle not explored). This suggests that puff characteristics collected from one cigarette may be representative of smoking patterns and can capture individual differences in smoking reward. Topography measures may be used efficiently and reliably to provide more comprehensive interventions to those with more intense topography and increase the likelihood of abstinence, though this may be most useful for male smokers. For female smokers, the relationship between ovarian hormone levels and smoking reinforcement determined via topography should continue to be explored and may be used further to inform the appropriate start of treatment regimens and target quit dates. Thus, further investigation of the effects of gender on smoking cessation may lead to more efficacious gender-based interventions. Finally, since topography represents a method to capture toxin exposure in smokers (Melikian et al., 2007), it also offers the potential to educate smokers regarding their puffing characteristics and subsequent exposure to the most harmful constituents of cigarette smoke.

This study has several limitations. Only female participants were enrolled, and so conclusions regarding a topography-abstinence relationship that is more robust in men must be tempered until future studies are conducted. Topography in this study was collected during a laboratory session that required overnight abstinence, as well as cue-reactivity testing prior to smoking. Thus, while all topography measures were collected under uniform conditions, these factors may have affected topography characteristics. Abstinence outcomes in the current study were influenced by the presence of active medication, which may have obscured a topography-abstinence relationship. Finally, this study did not fully explore the influence of demographic and other smoking characteristics on abstinence outcomes (results forthcoming).

5. Conclusions

Smoking topography characteristics may be clinically useful to predict abstinence outcomes in smokers with and without medication, but our results suggest that a predictive topography-abstinence relationship may be weak among female smokers, and perhaps more pronounced and therefore clinically relevant in male smokers. Our results provide support for and may be attributable to the hypothesis that the maintaining variables of smoking that are more behavioral, rather than pharmacological for women. Female smokers seem to have greater difficulty with cessation, and predictors of relapse should be identified to tailor treatment. Additionally, characteristics of smoking topography should be explored within the context of ovarian hormones levels, as their influence on topography, craving, and relapse is still largely unknown.

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Highlights

- Studies with adult and adolescent smokers have shown predictive relationships between less intense tobacco puffing characteristics and eventual abstinence.
- These relationships have not been explored in female cigarette smokers, who show less intense smoking patterns, but also more difficulty in quitting.
- This study examined the relationship between cigarette puff characteristics (i.e., smoking topography) and abstinence outcomes in adult female smokers.
- Results showed little evidence of a topography-abstinence relationship among female smokers, aside from a significant association between longer puff duration and greater puff volume and continued smoking during the active 4-week treatment phase, but only within the nicotine patch group.
- These data suggest a potentially weak topography-abstinence relationship among female smokers, and the possibility that prior evidence of a predictive relationship may be attributable to the inclusion of male smokers.

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Table 1

Demographic, smoking, and topography characteristics for enrolled participants.

Demographic, Smoking, and Topography Characteristics	All Participants (n=135)
Age mean, ± SD	31.9 ± 7.6
Treatment with VAR %, (#)	48.1 (65)
Caucasian	79.3 (107)
Smoking Characteristics	
Total Years Smoking	13.7 ± 7.8
Cigarettes Per Day	16.2 ± 7.0
Live with a Smoker % (#)	54.1 (73)
Previous Quit Attempts	3.1 ± 3.5
Fagerström Test for Nicotine Dependence (FTND) Total Score	4.9 ± 2.2
Questionnaire on Smoking Urges (QSU) Total Score	4.0 ± 1.3
QSU Factor 1	5.0 ± 1.6
QSU Factor 2	3.0 ± 1.4
Topography Measures on 1st Cig	
Number of Cigarettes Smoked	--
Number of Puffs per Cigarette	12.5 ± 4.4
Puff Volume (ml)	51.0 ± 17.0
Total Puff Volume (ml)	621 ± 248
Puff Avg. Flow (ml/sec)	32.7 ± 9.1
Puff Peak Flow (ml/sec)	46.4 ± 14.8
Puff Duration (mSec)*	1562 ± 464
Topography Measures on all Cigs	
Number of Cigarettes Smoked	2.9 ± 1.0
Number of Puffs per Cigarette	11.7 ± 3.9
Puff Volume (ml)*	49.9 ± 15.8
Total Puff Volume (ml)	1655 ± 796
Puff Avg. Flow (ml/sec)	32.8 ± 8.2
Puff Peak Flow (ml/sec)	46.0 ± 13.8
Puff Duration (mSec)*	1555 ± 458

Each smoking topography measure was calculated for the first cigarette smoked during the 1-hour ad-libitum period, as well as for all cigarettes smoked. Asterisks indicate significant treatment group differences (TNP vs. VAR) at $p < 0.05$.

Table 2

Risk Ratio predicting smoking versus abstinence during various time points for a one standard deviation increase in each smoking topography measure.

	Puff Volume (ml)		Total Puff Volume (ml)		Average Flow (ml/sec)		Peak Flow (ml/sec)		Duration (msec)	
Abstinence Outcomes	**RR (95% CI)**	**P**	**RR (95% CI)**	**P**	**RR (95% CI)**	**P**	**RR (95% CI)**	**P**	**RR (95% CI)**	**P**
First Cigarette Smoked										
Last 7 Days	0.87 (0.69–1.11)	0.263	0.93 (0.70–1.23)	0.591	0.87 (0.69–1.09)	0.230	0.89 (0.71–1.12)	0.325	0.97 (0.76–1.25)	0.830
Last 2 Weeks	1.01 (0.76–1.34)	0.962	1.03 (0.74–1.45)	0.844	0.89 (0.68–1.17)	0.416	1.01 (0.78–1.31)	0.944	1.14 (0.84–1.56)	0.397
Last 4 Weeks	1.01 (0.69–1.47)	0.962	1.22 (0.75–1.97)	0.418	0.84 (0.58–1.22)	0.353	0.97 (0.68–1.38)	0.859	1.44 (0.95–2.19)	0.089
Follow Up - 7 Day PPA	1.00 (0.65–1.56)	0.984	0.99 (0.62–1.58)	0.966	0.87 (0.58–1.30)	0.499	0.95 (0.66–1.38)	0.786	1.42 (0.92–2.19)	0.116
All Cigarettes Smoked										
Last 7 Days	0.90 (0.71–1.14)	0.380	1.03 (0.78–1.37)	0.809	0.90 (0.72–1.14)	0.388	0.93 (0.74–1.17)	0.552	0.96 (0.75–1.23)	0.731
Last 2 Weeks	1.05 (0.78–1.42)	0.759	1.10 (0.78–1.55)	0.590	0.92 (0.70–1.21)	0.570	1.05 (0.80–1.38)	0.705	1.13 (0.83–1.54)	0.446
Last 4 Weeks	1.09 (0.72–1.65)	0.699	1.46 (0.87–2.45)	0.156	0.86 (0.57–1.30)	0.479	1.01 (0.69–1.49)	0.950	1.39 (0.85–2.28)	0.194
Follow Up - 7 Day PPA	0.99 (0.67–1.46)	0.964	1.01 (0.65–1.57)	0.970	0.73 (0.51–1.05)	0.089	0.87 (0.62–1.21)	0.406	1.51 (0.98–2.35)	0.064

Data are shown as the risk ratio and 95% confidence interval of smoking versus abstinence for a one standard deviation unit increase in the topography measures adjusted for treatment assignment from parent study (VAR vs. TNP). Abstinence was determined based on an intent-to-treat sample and missing data were assumed as smoking at various time points. Units of change (one Standard Deviation) in smoking topography measures used for RR calculations (first cigarette smoked, all cigarettes smoked): Per Puff Volume (16.9, 15.9 mL), Total Puff Volume (255, 793 mL), Average Flow per Puff (9.0, 8.2 mL/Sec), Peak Flow per Puff (14.7, 13.8 mL/Sec), and Puff Duration (464,457 msec). PPA refers to 7-day point prevalence abstinence at the 8-week follow-up visit.