

Smoking Rates and Topography Predict Adolescent Smoking Cessation Following Treatment with Nicotine Replacement Therapy

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Abstract

Establishing measurement invariance of tobacco addiction among adolescents remains challenging. In adult smoking cessation trials, poor outcome is predicted by high cigarette consumption and large puff volume at baseline. We examined the predictive value of pretreatment smoking rates and topography variables for abstinence outcomes among 66 adolescents enrolled in a 3-month smoking cessation trial using nicotine replacement and cognitive behavioral therapy. Pretreatment variables included cigarettes per day (CPD), puff volume, puff duration, and several youth-adapted Fagerström-derived questionnaire scores. Outcome measures included prolonged abstinence at end of treatment and point-prevalent abstinence 3 months after the end of the

trial. Logistic regression controlling for treatment group showed that increases in baseline CPD (odds ratio, 1.438; 95% confidence interval, 1.051-1.967) and average puff volume (odds ratio, 1.168; 95% confidence interval, 1.030-1.326) predicted continued smoking at the end of treatment. Puff volume ($P = 0.013$), but not CPD, predicted abstinence at the 3-month follow-up. None of the youth-adapted Fagerström questionnaires predicted outcome on either abstinence measure. If confirmed in a larger sample, our findings suggest that puff topography, and possibly CPD, might predict cessation outcome better than Fagerström scores in adolescent smokers. (Cancer Epidemiol Biomarkers Prev 2006;15(1):154-7)

Introduction

Despite a recent decline in cigarette smoking among U.S. adolescents, rates of tobacco use remain quite high. Among middle school and high school students in the U.S., smoking in the past month averaged 10.1% and 22.9%, respectively (1). The mean age most teenagers start to smoke is ~14 years old (2). After the onset of intermittent smoking, symptoms of tobacco dependence often develop rapidly in adolescent smokers (3). Furthermore, when adolescent smokers try to quit, they experience withdrawal signs and symptoms similar to those of adult smokers (4). By age 17, many adolescent smokers recognize their tobacco dependence (5) and many have unsuccessfully attempted to quit (6). Success rates among adolescents in smoking cessation trials have lagged behind those of adults (7). Among adult smokers, lower levels of dependence are associated with greater ability to quit smoking (8). However, the absence of a universally accepted measure of dependence, especially for adolescents (9), complicates the assessment of treatment efficacy and impedes progress in tailoring interventions for tobacco dependence in youth.

Previous research with adolescents has shown that occasional smokers have more quitting success than daily smokers; however, other relevant "adult" measures of dependence did not predict cessation outcome among daily adolescent smokers (10). Although instruments initially developed for adults have been directly applied or modified for assessing adolescent

smoking, recent research suggests that, for youth, they have poor construct validity and low internal validity, failing to fully capture the broad dimensions of adolescent nicotine dependence (11). Items on these scales [cigarettes per day (CPD), smoking in spite of illness, avoiding places where smoking is prohibited, etc.] typically apply to adults who have relatively unhampered access to cigarettes and greater ability to determine when and where they smoke (11). The convergence of parental, social, and legal smoking prohibitions may reduce the validity for adolescent smokers of dependence-related questions that are relevant to an adult smoker (e.g., "Do you find it difficult to refrain from smoking in places where it is forbidden?"). Broad restrictions on underage smoking might artificially alter adolescent smoking patterns with respect to those dictated by actual level of tobacco addiction. Likewise, time to first cigarette of the day may be less reflective of dependence, and more indicative of parental interdictions or other social constraints. Thus, for adolescent smokers, it is important to identify markers independent of the environment that reflect level of tobacco dependence and ability to successfully stop smoking.

In a recent study, Strasser et al. (12) identified smoking-topography measures that predicted successful cessation among adult smokers trying to quit while using nicotine replacement products (nasal spray and patch). Among these adults, cessation was predicted by lower puff volumes, lower puff velocities, and greater interpuff intervals. Similarly, among adolescent smokers, self-reported depth of inhalation was linked to the severity of tobacco-withdrawal symptoms (13). Because adolescents often report variable patterns of smoking (14), behavioral measures that characterize addiction independently of established smoking patterns may be particularly relevant. Furthermore, several revised questionnaires developed to measure adolescent dependence have included items that attempt to quantify the depth of smoke

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Table 1. Sample characteristics and markers of smoke exposure by 3-month prolonged abstinence status

Baseline measure	Sample average (<i>n</i> = 66)	Outcome (prolonged abstinence)		<i>t</i> test
		Abstinent (<i>n</i> = 8)	Smoking (<i>n</i> = 58)	
Age (y)	15.1 ± 1.3	15.4 ± 0.9	15.1 ± 1.4	not significant (<i>P</i> > 0.2)
Age at first cigarette (y)	11.4 ± 2.0	11.3 ± 1.1	11.9 ± 2.2	not significant (<i>P</i> > 0.2)
Fagerström test of nicotine dependence score	7.17 ± 1.30	6.5 ± 0.76	7.3 ± 1.3	<i>t</i> = 1.57 (<i>P</i> = 0.121)
CPD	19.0 ± 8.4	13.0 ± 2.6	19.8 ± 8.6	<i>t</i> = 2.20 (<i>P</i> = 0.032)
Puff volume (mL)	36.0 ± 13.5	25.2 ± 8.0	37.5 ± 13.4	<i>t</i> = 2.53 (<i>P</i> = 0.014)
Puff duration (s)	1.06 ± 0.43	0.70 ± 0.25	1.11 ± 0.43	<i>t</i> = 2.64 (<i>P</i> = 0.010)
Puff interval (s)	18.2 ± 10.6	23.57 ± 14.3	17.4 ± 11.8	<i>t</i> = -1.34 (<i>P</i> = 0.184)
Mean puff velocity	35.6 ± 10.6	37.2 ± 8.8	35.4 ± 10.9	not significant (<i>P</i> > 0.2)
Expired-air CO	10.1 ± 6.4	6.25 ± 2.38	10.67 ± 6.58	<i>t</i> = 1.87 (<i>P</i> = 0.066)

inhalation (4). However, no studies conclusively indicate either the reliability of exposure variables to measure dependence or predict successful cessation in dependent adolescent smokers.

In the present study, we hypothesized that high baseline smoking rates and topography measures would inversely predict smoking cessation among adolescent smokers enrolled in a trial using nicotine replacement therapy in combination with cognitive behavioral therapy (7).

Materials and Methods

Participants. Adolescent tobacco smokers were recruited through television, radio, and print advertisements in Baltimore, MD as part of a randomized double-blind double-dummy placebo-controlled trial testing the safety, efficacy, and tolerability of two forms of nicotine replacement therapy, the nicotine patch or nicotine gum, in conjunction with cognitive behavioral therapy (7, 15). Because the protocol included nicotine replacement therapy for participants who were 13 to 17 years of age, the National Institute on Drug Abuse Institutional Review Board and the Food and Drug Administration approved the study for adolescents who had smoked at least 10 CPD for 1 year and had a Fagerström test of nicotine dependence score ≥ 5 (16). Pregnant girls, adolescents who had recently used nicotine replacement therapy, those with an untreated acute psychiatric disorder (including current drug or alcohol dependence), and those who lacked parental permission were excluded from this study.

Demographics, Smoking History, and Biochemical Measures. Participants were prescreened at the time of treatment request using an internally developed telephone interview. Screening interviewers collected demographic information (age, gender, and ethnicity), smoking rates, and smoking history. Questions from both adult and youth-adapted Fagerström-derived questionnaires were gathered into a "Universal" Fagerström. Questionnaires included were: the Fagerström tolerance questionnaire (17), the Fagerström test for nicotine dependence (16), the heavy smoking index (18), and two youth-adapted Fagerström tolerance questionnaires (4, 19). Further on-site screening involved a detailed history and physical examination, a psychiatric assessment, and baseline measures of expired-air CO.

Topography Measures. Participants reported to the smoking-topography laboratory during their first on-site screening visit, ~1 week before the scheduled quit date. The topography unit was placed in a ventilated chamber and a nurse was present at all times during the experiment. Participants smoked a single cigarette of their usual brand through a plastic mouthpiece connected to an analog/digital converter by a plastic tube. The computer-based smoking-topography unit (Clinical Research Support System, Plowshare Technologies, Baltimore, MD) calculated and stored data on each puff

for puff volume, puff duration, interpuff interval, and mean puff velocity. For each participant, topography measures were obtained by averaging the variables from the first five artifact-free puffs, as previously reported (20, 21). The first and last puffs of the cigarette were not included in the averages.

Treatment Procedures. The study timeline consisted of two baseline visits, 11 treatment visits over 12 weeks, and a 3-month post-quit follow-up visit. At each treatment visit, participants attended 45-minute cognitive behavioral group therapy sessions led by a trained social worker (15). Participants were also randomly assigned to one of three groups: Active patch/placebo gum, active gum/placebo patch, or placebo gum/placebo patch (due to an extremely low rate of abstinence in the third group, the present analyses include only data from adolescents in the first two groups, i.e., those receiving active nicotine replacement therapy). After the baseline visits, participants were enrolled in their treatment phase and returned for their scheduled quit date. On the quit date, participants were instructed to use the gum as needed (with the approximate recommended daily use being equivalent to half of their baseline CPD) and to apply a new patch daily (7).

Outcome Measures. Participant smoking status was assessed at each visit through self-report and expired-air CO. Point-prevalence abstinence at each visit was defined as self-reported abstinence from smoking and an expired-air CO level of no more than 6 ppm. Prolonged abstinence was defined as point-prevalent abstinence maintained throughout the 12 weeks of the trial, with the exception of an initial 2-week grace period immediately following the quit date (22). Abstinence at follow-up was also based on a self-report of no smoking during the 3 months since the end of treatment and an expired-air CO of <6 ppm.

Data Analysis. Descriptive statistics were calculated to characterize demographic variables, smoking patterns, and topography measures. Because this was a sample of convenience, the sample size was dictated by the power analysis for the clinical trial. Predictors of abstinence were first examined

Table 2. Logistic regression model for measures predicting the odds of continued smoking at the end of treatment, controlling for treatment group allocation

Predictor	Continued smoking	
	Odds ratio (95% confidence interval)	<i>P</i>
Expired-air CO	1.18 (0.826-1.695)	0.358
Mean puff velocity	0.914 (0.825-1.012)	0.083
CPD	1.438 (1.051-1.967)	0.023
Puff volume (mL)	1.168 (1.030-1.326)	0.016

Table 3. Independent *t* tests for predictors of abstinence at 3-month follow-up

Baseline measure	Average of baseline measures based on follow-up status		<i>t</i> test
	Abstainers (<i>n</i> = 10)	Nonabstainers (<i>n</i> = 56)	
Expired-air CO	8.1 ± 7.1	10.5 ± 6.2	<i>t</i> = 1.10 (<i>P</i> = 0.279)
Mean puff velocity	33.5 ± 9.0	36.0 ± 10.9	<i>t</i> = 0.70 (<i>P</i> = 0.488)
CPD	14.4 ± 3.8	19.8 ± 8.8	<i>t</i> = 1.90 (<i>P</i> = 0.062)
Puff volume (mL)	26.4 ± 7.0	37.8 ± 13.6	<i>t</i> = 2.56 (<i>P</i> = 0.013)

in bivariate tests (χ^2 tests for categorical measures and *t* tests for continuous variables). Topography measures and covariates with *P* values below an initial threshold of 0.20 were tested in a backward stepwise logistic regression model of continued smoking along with treatment group (patch versus gum) which was selected a priori as a controlling variable. Because no measure of nicotine dependence has shown predictive validity for adolescents receiving nicotine replacement therapy, dependence level was not designated as a controlling variable. Topography variables with *P* > 0.2 associations were dropped from the model. Predictors contributing to the stepwise model were compared using *t* tests to determine their associations with smoking abstinence at the 3-month follow-up visit. All analyses were done on an intent-to-treat basis. *P* < 0.05 was used as a test of significance.

Results

Sample Characteristics. Of the 66 adolescents, 64% were female; 73% were Caucasian, 24% African-American, and 3% of other ethnicities. High smoking rates and Fagerström test of nicotine dependence scores indicated substantial consumption and dependence (see Table 1). At the end of the 3-month treatment period, 12% of participants had achieved prolonged abstinence; at the 3-month follow-up, 15% were point-prevalent abstinent.

Predictors of Abstinence

End of treatment. Abstinence rates in this sample did not significantly differ as a function of any baseline Fagerström-derived questionnaire scores. Abstinence was also not associated with age, years of smoking, age of first cigarette, or treatment group (patch versus gum). End-of-treatment abstinence was predicted by baseline CPD and by several baseline topography variables (see Table 1). Logistic regression analyses controlling for nicotine-treatment group showed that increased puff volume and CPD were associated with continued smoking (see Table 2). A negative association of mean puff velocity with continued smoking showed a trend towards significance. Interpuff interval and puff duration were not significantly associated with treatment outcome. No significant interactions between treatment groups and predictors were found.

Three-month follow-up. Puff volume was significantly associated with abstinence at the 3-month posttreatment follow-up. Additionally, CPD showed a trend toward association with abstinence at follow-up, but expired-air CO and mean puff velocity were not significantly associated with abstinence (see Table 3).

Discussion

The high toll of smoking in youth dictates the need to uncover predictors of successful adolescent smoking cessation. It is conceivable that predicting cessation success in younger smokers may require a multimodal approach for

assessing tobacco dependence. The main finding of this study is that smoking rates and puff volume inversely predicted end-of-treatment prolonged abstinence in dependent adolescent cigarette smokers undergoing treatment for cessation: youths who remained abstinent until the end of treatment had smaller puff volumes and lower baseline smoking rates. In addition, the strict criterion of prolonged abstinence suggests that these smokers had really achieved smoking cessation, rather than a mere transient period of abstinence. The association of puff volume with abstinence at the 3-month follow-up further strengthens the case for the predictive validity of puff volume among adolescent smokers. None of the youth-adapted Fagerström questionnaires predicted abstinence at the end of treatment or at follow-up.

Among adults, compensatory alterations in smoking topography have been examined within a reduction paradigm (23, 24). Broad restrictions on underage smoking suggest that adolescent smokers would also be highly susceptible to such effects (11). Considering increased puff volume as a behavioral measure of smoking compensation may circumvent confounds associated with a wide array of factors altering daily adolescent smoking rates.

The results of the present study indicate that markers of the frequency and intensity of smoke exposure such as CPD and smoking-topography measures are useful predictors of adolescent smoking cessation, and by proxy, degree of tobacco dependence. The findings presented are limited by our sample size and by the unequal distribution of outcomes in our sample (58 smokers, 8 abstainers). In a post hoc power analysis, we found that Fagerström test of nicotine dependence scores would have significantly predicted abstinence if our sample had been enlarged to include 132 smokers and 18 abstainers. The clinical significance of such an effect seems to pale in comparison with the effects we did detect.

The findings are also limited by our selection criteria, which were designed to recruit tobacco-addicted adolescents. As a result, these findings may not be generalizable to youths who are experimenting with smoking and have not graduated to high levels of daily smoke exposure. Additionally, the knowledge gained herein was from methodology limited to a research setting (topography machine). Whether a self-reported measure of puff volume or depth of inhalation could serve as a clinically relevant marker requires further study.

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