Original investigation

Characteristics of Adult Cigarette Smokers Who “Relight” and the Effects of Exposure to Tobacco Smoke Constituents

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Abstract

Introduction: About half of smokers relight their cigarette, a habit that is a risk factor for chronic bronchitis and possibly lung cancer. Little is known about the characteristics of smokers who relight and their dependence on nicotine. It is unknown whether relighting affects exposure to tobacco smoke constituents. This study examined the characteristics of lighters of usual brand cigarettes and whether relighting affects exposure to selected tobacco smoke constituents.

Methods: We explored relighting status and frequency, using baseline data from 248 adult smokers participating in studies of reduced nicotine cigarettes in relation to demographic and cigarette characteristics, smoking behaviors, nicotine dependence, biomarkers of exposure (exhaled carbon monoxide, blood cotinine), and biomarkers of oxidative stress (ratio of oxidized/reduced glutathione).

Results: 69.4% ($n = 172$) of subjects reported relighting, and they relit an average of five cigarettes out of 20. Both lighters and non-lighters smoked a mean of 20 cigarettes per day ($p = .6$). Relighting was significantly associated with higher nicotine dependence, use of longer rod cigarettes, older age, lower income, and unemployment. There were no significant associations between relighting and blood cotinine, exhaled carbon monoxide or measures of oxidized/reduced blood glutathione.

Conclusions: The majority of subjects were lighters, who had higher levels of nicotine dependence than non-lighters. Lighters had similar levels of plasma cotinine and exhaled carbon monoxide to non-lighters.

Implications: No study has compared the cigarette characteristics and biomarkers of exposure of adult cigarette smokers who relight with those who do not. Relighting behavior was common in our sample and was associated with low income, not currently working, higher nicotine dependence, cigarette rod length, daily cigarette use years, and a lifetime history of depressed mood.

Introduction

Tobacco use is the leading cause of preventable disease and death in the United States, and cigarettes are the most commonly used tobacco product among US adults.¹⁻³ Despite the known addictive and harmful properties of cigarettes, nearly 40 million US adults still smoke, and each year, nearly half a million die prematurely due to their smoking.^{1,3} The Family Smoking Prevention and Tobacco Control Act (TCA) granted the US Food and Drug Administration (FDA) Center for Tobacco Products (CTP) the broad authority to regulate all tobacco products and to develop product standards that could decrease the harm and/or addictiveness of tobacco products.⁴ To inform future regulatory activities toward product standards and to provide a sound scientific basis for meeting the demands of the TCA, the National Institutes of Health (NIH) and the FDA CTP fund research studies to better understand smoking behaviors, tobacco smoke constituents, and/or design features that affect the addictiveness of cigarettes.⁵ Recent data from a US national survey found that the prevalence of cigarette smoking among adults declined from 20.9% in 2005 to 15.5% in 2016 ($p < .0001$).³ In addition among remaining smokers there is consistent evidence of a reduction in the average daily cigarette consumption.^{3,6} However, Jarvis et al.⁶ reported that while average cigarette consumption has declined, nicotine intake per cigarette has increased. One possibility is that as cigarettes have become more expensive and smoke-free policies more widespread, more smokers may be using the practice of extinguishing a smoked cigarette and later relighting it to smoke it again (butting out). The prevalence and effects of this practice has public health implications as some prior studies have suggested that it is associated with increased dependence and health effects.⁷⁻¹⁰

Typically, the presence or absence of relighting behavior is not captured when researchers assess cigarette consumption via the most commonly used measure of cigarettes per day (CPD). The reasons for relighting are not well understood but may reflect financial considerations. Smokers with lower incomes may seek to extract more nicotine per cigarette and may be more likely to preserve/conservate their purchased products than more affluent smokers. However, when assessing dependence and collecting CPD data, it is typically assumed that an individual is smoking only one cigarette in its entirety during one session. In practice, researchers do not account for whether an individual may extinguish and relight the same cigarette at a later time point. Relighting is not taken into account in measures of nicotine dependence such as the Fagerström Test for Nicotine Dependence (FTND).^{11,12} If relighting is not considered in conjunction with CPD, then FTND and other nicotine dependence scales may be underestimating nicotine dependence and toxicant intake.

In a review of the literature, we found only four studies specifically related to relighting. The first known study was conducted by Dark et al.⁷ in 1963 in Great Britain which evaluated 1000 male smokers who attended outpatient clinics for chest disorders. Out of all smokers, 438 relit their cigarettes, 40.4% of which had lung cancer compared with 27.8% of 562 non-relighters ($p < .001$). The authors suggested that relighting cigarettes significantly contributed to lung cancer risk.⁷ This study was conducted during a period of time when most smokers had a history of smoking primarily unfiltered cigarettes. In another early study, Rimington investigated 5438 male smokers of which 1501 were relighters.⁸ The study aimed at addressing symptoms related to chronic bronchitis (eg, produced sputum from chest 3 months of the year for at least the last 2 years). Among all smokers, those who relit their cigarettes had a significantly higher prevalence of chronic bronchitis (39.7%) compared

with non-relighters (32.9%) ($p < .001$). A third study conducted in Canada assessed relighting behavior among 434 daily smokers.⁹ Overall, 230 (53%) smokers reported relighting their cigarettes at least sometimes. Characteristics found to be positively correlated with relighting included higher cigarette dependence, being female, unemployment, lower income, lower education status, and no intentions to change smoking behavior compared with non-relighters. The most recent relighting study examined the characteristics of 496 subjects who were seeking tobacco treatment.¹⁰ The researchers found that 230 (46.4%) patients reported relighting their cigarettes. Additional characteristics of these relighters, not previously reported, included being African American, being sick or disabled, smoking menthol cigarettes, and waking at night to smoke. These studies suggest that relighting behavior is fairly common and possibly correlated with health effects. However, whether relighting affects exposure to tobacco smoke remains unknown. This study examined the characteristics of adult smokers who extinguished and relit their usual brand cigarettes and assessed whether this behavior affected exposure to selected tobacco smoke constituents.

Methods

Overall Trial Study Design and Subjects

This study was a cross-sectional analysis of baseline characteristics from visits 1 and 2 of two similarly designed reduced nicotine content (RNC) cigarette randomized trials (project 1 and project 2). The trial protocols, including the study design and inclusion/exclusion criteria, were explained in detail elsewhere.^{13,14} Briefly, our sample consists of smokers of five or more CPD, with no intention to quit, aged 18–65, who had less than 16 years of education (project 1) and/or had comorbid mood and/or anxiety disorders (project 2). At visit 1, subjects were asked a series of screening questions about demographics, medical and tobacco use histories, current cigarette brand details, and cigarette use behaviors. After study eligibility was determined, biological measurements were obtained (eg, exhaled carbon monoxide, eCO) and subjects completed baseline questionnaires.^{13,14} Subjects were instructed to keep track of the number of their usual brand cigarettes smoked each day for 1 week in a distributed cigarette log.¹⁴ At visit 2, subjects returned to the study sites and provided their completed cigarette logs from the prior week. Biological measurements were obtained (similar to visit 1) and blood and urine samples were collected. The studies were approved by the institutional review boards at each study site.

Characteristics of Analytical Sample

The present analysis utilizes the baseline assessment data collected from subjects during the time they smoked their usual brand cigarettes (visits 1 and 2) for both projects. Only consented subjects who attended both baseline phase visits (1 and 2) and had biomarker measurements for blood glutathione, blood hemoglobin, and plasma cotinine (>15 ng/mL) at the time of this analysis were included ($n = 248$).

Demographics

Subject characteristics (eg, age, sex, race, ethnicity, education, employment status, income, relationship status, and sexual orientation) were self-reported at the first baseline assessment (visit 1). Education attained was categorized as less than high school, completed high school or received a GED/equivalent, and more than high school. Employment status was categorized as currently working or

not currently working. Income was categorized as low (\$0–\$19 999), middle (\$20 000–\$59 999), and high (\$60 000+).

Cigarette Logs, Subjective Questionnaires, and Psychological Assessment

Subjects were asked about their cigarette consumption using the number of cigarettes smoked per day as they recorded in their daily log. Mean CPD was calculated by adding the number of cigarettes reportedly smoked on each day and then dividing the total number of cigarettes consumed in the 6 days before visit 1 and visit 2 (taking an average of all days for which data was recorded on the daily logs at visit 2). Relighting behavior of their usual brand of cigarettes was determined at visit 1 by the question, “Do you sometimes ‘butt out’ or extinguish and relight your cigarettes [Yes/No]?” If subjects responded “Yes,” a follow-up question was asked to determine the number of cigarettes that were relit: “In the last week, on average, how many out of a pack of 20 cigarettes that you smoke, do you typically re-light?” Data was also collected on their usual brand cigarette details at visit 1, including cost per pack (in US dollars), cigarette rod length (summarized into two length categories of 72 mm/85 mm [regular/king] and 100 mm/120 mm [longs/ultra-longs]), how their cigarettes are typically purchased (pack, carton, or hand-rolled/made with a machine), and flavor (menthol/non-menthol). Nicotine dependence was measured using the FTND,^{11,12} the Hooked on Nicotine Checklist (HONC),^{15,16} and the Penn State Cigarette Dependence Index (PSCDI).¹⁷ Lifetime history of depressed mood was determined by subjects’ response of “Yes” to the following question, “In your lifetime, have you ever had two weeks or more when nearly every day you felt sad, blue, depressed [Yes/No]?”^{18,19}

Biomarkers

eCO (in parts per million [ppm]) was measured using a handheld noninvasive eCO monitor (Bedfont piCO+ Smokerlyzer, <https://www.bedfont.com/>).²⁰ Blood samples obtained were used to measure plasma cotinine, blood hemoglobin, and blood glutathione levels. Cotinine concentration levels in plasma were measured using a solid-phase, enzyme-linked immunosorbent assay (ELISA) kit from Calbiotech (El Cajon, CA).²¹ The assay was carried out as directed by the manufacturer. Total glutathione (μmol GSH equivalents), a tripeptide that protects against oxidative stress in cells and tissues, was measured in whole blood using Ellman’s Reagent 5,5′-dithio-bis-(2-nitrobenzoic acid) (DTNB) enzymatic recycling micromethod.^{22,23} Levels of free (reduced) GSH and oxidized glutathione (GSSG) were determined in metaphosphoric acid extracts. Acid insoluble pellets were used for the analysis of protein-bound GSH (GSSP) following reduction with potassium borohydride (KBH_4) and reacidification with metaphosphoric acid.²⁴ Total glutathione was expressed as micromoles of GSH equivalents per gram of hemoglobin. Hemoglobin measurement was expressed as grams per milliliter. The 2GSSG/GSH, GSSP/GSH, and (2GSSG+GSSP)/GSH ratios were also determined.

Statistical Analysis

Study data were collected and stored using REDCap electronic data capture tools (a secure, web-based application used for research studies) hosted at the Penn State Milton S. Hershey Medical Center and College of Medicine.²⁵ Data management and preparation for analysis (eg, recoding) were performed using R version 3.4.2 (R foundation, <https://www.r-project.org/>). Summary statistics and

data analysis were analyzed using SAS 9.4 (SAS Institute, Inc., Cary, NC). Relighters were divided into subgroups of infrequent relighters and frequent relighters according to the number of cigarettes reportedly relit per pack. Given the distribution of the relighting frequency and the average reported number of cigarettes relit (five cigarettes per pack of 20) for those who reported relighting behavior, five relit cigarettes was used as the cut-point to distinguish infrequent (relight < 5 per pack) from frequent (relight $\geq$ 5 per pack) relighters. Note that one subject reported relighting behavior, but did not report a relighting frequency ($n = 171$). Ordinal statistical analyses treated relighting status as an outcome measure, a gradient from no relighting behavior to frequent relighting behavior. Ordinal logistic regression models (also known as proportional odds or cumulative logistic regression) were used to assess the significance of characterizing effects when modeling relighting status as an ordinal outcome measure. Binary statistical analyses (relighters vs. non-relighters) were also explored (data not shown) using chi-square tests, Fisher’s Exact tests (categorical measures), Mantel-Haenszel chi-square tests for trend (ordinal measures), and Wilcoxon Rank Sum tests (continuous measures), where appropriate. All tests were two-sided using a significance level of .05.

Results

Overall Subject Characteristics

This analysis summarized 248 subjects with a mean age of 44 years who have been smoking cigarettes daily for about 26 years, on average. Socio-demographics, cigarette characteristics, and behavior patterns are shown in Table 1. The subjects reported smoking about a pack per day, on average (mean CPD of 20) with an average eCO of 30 with moderate (FTND score of 6.0) and high (PSCDI score of 13.3, HONC score of 7.7) dependence levels of nicotine addiction. Most subjects smoked cigarettes with longer rod lengths (≥ 100 mm) (53.2%), smoked menthol flavor (54.8%), and purchased their cigarettes by the pack at a mean cost of \$5.95 (Table 1).

Relighting Characteristics

The majority of subjects ($n = 172$, 69.4%) reported extinguishing and relighting their usual brand cigarettes, and reported relighting an average of five (SD = 4.3) cigarettes per pack.

Table 1 reports that older subjects were more likely to relight more frequently than younger subjects ($p < .001$), and that Caucasians and non-Hispanics were more likely to relight less frequently than African Americans ($p = .01$) and Hispanics ($p = .02$), respectively. Those currently employed and those with higher incomes were more likely to relight less frequently than those currently unemployed ($p < .001$) and those with lower incomes ($p < .001$), accordingly. Those who awakened at night to have a cigarette were more likely to relight more frequently ($p < .001$) than those who did not, and those smoking cigarettes of shorter rod lengths were more likely to relight less frequently than those smoking longer rod lengths ($p < .001$). Analyses of these baseline demographics and cigarette characteristics when treating relighting status as a binary indicator variable showed a similar pattern of results, with the exception of race, ethnicity, and lifetime history of depressed mood (data not shown). Compared to non-relighters, relighters were about 4 years older on average, less likely to be currently working, more likely to have lower income, more likely to awaken at night to have a cigarette, more likely to smoke cigarettes with longer rod lengths, and were more likely to

Table 1. Baseline Demographics and Cigarette Characteristics of Own-Brand Cigarettes by Relighting Frequency

	Non-relighters (<i>n</i> = 76)	Relighters of <5 cigarettes per pack (<i>n</i> = 94)	Relighters of ≥5 cigarettes per pack (<i>n</i> = 77)	<i>p</i> ^a
Female	47.4 (36)	55.3 (52)	61.0 (47)	.09
Age	41.2 (11.4, 19–65)	41.5 (13.0, 19–65)	48.2 (10.6, 23–65)	<.001
Race				
Caucasian/white	81.6 (62)	78.5 (73)	61.0 (47)	.01
African American/black	11.8 (9)	18.3 (17)	31.2 (24)	
Other	6.6 (5)	3.2 (3)	7.8 (6)	
Hispanic ethnicity				.02
Non-Hispanic/Latino	97.4 (74)	98.9 (92)	90.9 (70)	
Hispanic/Latino	2.6 (2)	1.1 (1)	9.1 (7)	
Education				
<HS	9.2 (7)	9.6 (9)	19.5 (15)	.08
HS	39.5 (30)	38.3 (36)	42.9 (33)	
>HS	51.3 (39)	52.1 (49)	37.7 (29)	
Employment				
Currently working	69.7 (53)	50.5 (47)	36.8 (28)	<.001
Not currently working	30.3 (23)	49.5 (46)	63.2 (48)	
Income				
\$0–\$19 999	19.4 (12)	34.6 (28)	51.8 (29)	<.001
\$20 000–\$59 999	41.9 (26)	39.5 (32)	33.9 (19)	
≥\$60 000	38.7 (24)	25.9 (21)	14.3 (8)	
Relationship status				
Married	26.3 (20)	23.4 (22)	24.7 (19)	.81
Not married	73.7 (56)	76.6 (72)	75.3 (58)	
Sexual identity				
Heterosexual	88.2 (67)	85.9 (79)	88.2 (67)	1.00
Lesbian/gay/bisexual	11.8 (9)	14.1 (13)	11.8 (9)	
Cigarette flavor				
Non-menthol	50.0 (38)	45.7 (43)	40.3 (31)	.23
Menthol	50.0 (38)	54.3 (51)	59.7 (46)	
Purchase by pack, carton, RYO				
Pack	68.4 (52)	74.5 (70)	77.9 (60)	.21
Carton	14.5 (11)	8.5 (8)	6.5 (5)	
Roll your own	17.1 (13)	17.0 (16)	15.6 (12)	
Awaken at night to have cigarette	29.0 (22)	47.9 (45)	72.7 (56)	<.001
Cigarette length				
72 mm (shorts) + 80–85 mm (kings)	64.5 (49)	42.6 (40)	33.8 (26)	<.001
100 mm (longs) + 120 mm (ultra-longs)	35.5 (27)	57.5 (54)	66.2 (51)	
Lifetime history of depressed mood symptoms	48.0 (36)	66.7 (62)	55.3 (42)	.37

Range = (minimum–maximum); continuous variables: report mean (SD, range); categorical variables: report column % (*n*).

^aSignificance of the effect modeling relighting status as an ordinal outcome via ordinal logistic regression.

have experienced a lifetime history of depressed mood ($p = .05$, marginal significance). Note that the subgroups when analyzing race and ethnicity have particularly small cell counts (Table 1). Interestingly, when treating relighting status as an ordinal measure of frequency and as a binary indicator measure, we did not observe any significant trends in self-reported CPD or in biomarkers of exposure (eCO, cotinine), despite those who relight more frequently (and relighters overall) reporting characteristics of greater addiction, smoking their first cigarette of the day sooner after waking and scoring higher on the FTND and PSCDI (Table 2). No significant associations were observed for biomarkers of oxidative stress (GSH, GSSH, and GSSP) with relighting behavior (binary or ordinal) (Table 3).

Discussion

Over one-half of our sample engaged in cigarette relighting behavior, with the majority (55.0%) of relighters reporting infrequent

relighting (<5 cigarettes per pack). Several characteristics were associated with more frequent relighting behaviors, such as older age, African American racial identity, Hispanic ethnicity, longer daily cigarette use, not currently working, lower income, and smoking longer rod cigarettes. Similar to previous research, we found that more frequent relighting behavior was associated with higher markers of nicotine dependence,^{9,10} including a sooner time to first cigarette of the day and awakening at night to smoke.¹⁰ Previous studies found that relighters smoked fewer CPD, and that relighting was a behavior associated with lower income.^{7,10} We found no significant trends with CPD in the current study, yet the preferred use of longer cigarettes among the relighting group suggests that longer cigarettes may have been perceived as a better value for the money, similar to the reporting by Agaku et al.²⁶ Since relighters are more nicotine dependent, they may have a difficult time trying to quit smoking. Implications for excluding relighting behavior from consideration in dependence measures could underestimate nicotine

Table 2. Baseline Summary Statistics of Smoking Behaviors and Cigarette Characteristics by Relighting Frequency

	Non-relighters of own-brand cigarettes (<i>n</i> = 76)	Relighters of < 5 cigarettes per pack (<i>n</i> = 94)	Relighters of ≥5 cigarettes per pack (<i>n</i> = 77)	<i>p</i> ^a
Years used cigarettes daily				
Mean (SD, range)	24.1 (11.7, 3.0–49.0)	24.8 (13.6, 1.0–49.0)	30.4 (10.7, 6.0–46.0)	.003
Median (IQR)	25.0 (15.0, 33.0)	24.0 (14.0, 37.0)	33.0 (23.0, 39.0)	
Time to first cigarette (TTFC) (min)				
Mean (SD, range)	24.5 (40.7, 1.0–300.0)	17.6 (23.9, 1.0–180.0)	9.0 (10.3, 0.0–180.0)	.002
Median (IQR)	10.0 (5.0, 30.0)	6.0 (5.0, 30.0)	5.0 (5.0, 10.0)	
Cost per cigarette (in US\$)				
Mean (SD, range)	0.29 (0.12, 0.02–0.55)	0.30 (0.13, 0.02–0.54)	0.31 (0.13, 0.01–0.52)	.30
Median (IQR)	0.32 (0.26, 0.35)	0.30 (0.27, 0.35)	0.33 (0.27, 0.38)	
Cost per pack, (in US\$)				
Mean (SD, range)	5.74 (2.49, 0.46–11.00)	5.90 (2.51, 0.47–10.84)	6.17 (2.69, 0.24–10.40)	.30
Median (IQR)	6.35 (5.19, 7.00)	6.00 (5.40–7.07)	6.69 (5.38, 7.50)	
Cigarettes per day (CPD)				
Mean (SD, range)	19.8 (9.7, 1.3–60.0)	19.9 (10.5, 3.3–58.0)	20.1 (10.1, 3–50.8)	.87
Median (IQR)	18.6 (14.2, 23.6)	18.2 (13.2, 23.8)	17.3 (13.0, 24.2)	
Exhaled carbon monoxide (eCO) (ppm)				
Mean (SD, range)	28.3 (13.5, 4.0–58.0)	29.0 (15.0, 5.0–85.0)	32.0 (18.0, 4.0–100.0)	.14
Median (IQR)	28.5 (17.0, 38.0)	27.5 (17.0, 37.0)	31.0 (21.0, 39.0)	
Cotinine (ng/mL)				
Mean (SD, range)	278.2 (134.8, 23.7–632.7)	283.6 (156.2, 34.9–918.0)	310.4 (146.3, 18.1–812.4)	.19
Median (IQR)	276.0 (156.5, 381.9)	261.9 (159.1, 361.7)	293 (212.3, 399.3)	
Cotinine per cigarette (ng/mL)				
Mean (SD, range)	15.6 (10.0, 2.3–84.1)	16.3 (9.4, 3.6–52.0)	17.7 (9.6, 3.3–51.6)	.15
Median (IQR)	13.9 (10.5, 18.9)	13.8 (9.5, 22.0)	15.8 (10.6, 23.7)	
Fagerström Test for Nicotine Dependence (FTND)				
Mean (SD, range)	5.6 (2.3, 0.0–10.0)	5.8 (2.1, 1.0–10.0)	6.8 (1.8, 2.0–10.0)	<.001
Median (IQR)	6.0 (3.5, 7.0)	6.0 (4.0, 7.0)	7.0 (6.0, 8.0)	
Penn State Cigarette Dependence Index (PSCDI) Score				
Mean (SD, range)	12.2 (3.4, 3.0–19.0)	13.2 (3.1, 5.0–20.0)	14.6 (3.1, 6.0–20.0)	<.001
Median (IQR)	12.0 (10.0, 15.0)	13.0 (11.0, 15.0)	15.0 (12.0, 17.0)	
Hooked on Nicotine Checklist (HONC) score				
Mean (SD, range)	7.4 (2.2, 0.0–10.0)	7.9 (2.1, 0.0–10.0)	7.7 (2.2, 1.0–10.0)	.30
Median (IQR)	8.0 (6.0, 9.0)	8.0 (7.0, 9.0)	8.0 (7.0, 9.0)	

Range = (minimum–maximum); IQR: interquartile range = (25th percentile, 75th percentile).

^aSignificance of the effect modeling relighting status as an ordinal outcome via ordinal logistic regression.

Table 3. Blood Levels of GSH, GSSG, and GSSP by Relighting Frequency

	Non-relighters (<i>n</i> = 76)	Relighters of <5 cigarettes per pack (<i>n</i> = 94)	Relighters of ≥5 cigarettes per pack (<i>n</i> = 77)	<i>p</i> ^a
Total Glutathione (μmol GSH equivalents/g Hb)	10.14 (2.90, 4.84–18.67)	10.0 (4.11, 3.55–24.86)	9.83 (3.60, 5.01–24.56)	.62
Hemoglobin (g/mL)	0.11 (0.01, 0.07–0.15)	0.11 (0.01, 0.07–0.15)	0.11 (0.01, 0.09–0.14)	.85
2GSSG/GSH	0.07 (0.03, 0.02–0.15)	0.08 (0.05, 0.02–0.28)	0.07 (0.03, 0.02–0.19)	.95
GSSP/GSH	0.15 (0.06, 0.05–0.41)	0.17 (0.09, 0.03–0.53)	0.15 (0.08, 0.02–0.32)	.50
(2GSSG + GSSP)/GSH	0.22 (0.08, 0.10–0.57)	0.25 (0.11, 0.06–0.58)	0.21 (0.09, 0.05–0.49)	.58

Mean (SD, range); range = (minimum–maximum); GSH = Reduced Glutathione; GSSG = Oxidized Glutathione; GSSP = Protein-Bound Glutathione; Hb = Hemoglobin.

^aSignificance of the effect modeling relighting status as an ordinal outcome via ordinal logistic regression.

and toxin intake and could cause prescribed pharmacotherapy to be less effective.

We did not observe any significant associations between nicotine exposure and relighting behavior. This finding may be explained, in part, by similar number of reported CPD. Additionally, national data shows, over time, the intake of nicotine has been stable among cigarette smokers.⁶ It is not surprising that no significant associations were observed between biomarkers of exposure (eCO, cotinine) or

oxidative stress (GSH) with relighting frequency, as previous research found that biomarkers (CO, cotinine) increase with CPD, but not in a linear manner, along with the notion that CPD alone is not necessarily a reliable measure of toxicant exposure and may be underestimated at low levels of smoking.²⁷ Both groups smoked about one pack of cigarettes on average; however nicotine dependence was significantly higher in relighters, which is similar to previous findings.^{9,10} This demonstrates the importance in considering

other factors when measuring nicotine dependence (eg, compensatory smoking).^{28,29} It will also be important to assess whether relighters include the number of times each cigarette is smoked when collecting information on CPD for future studies. The impact of relighting behavior on tobacco regulatory research should especially be considered for research in which subjects are provided with research cigarettes at no cost. Since relighters have a preference for longer rod cigarettes, they may smoke shorter cigarettes differently via compensation to satisfy their nicotine addiction, particularly if the research cigarettes are provided free of charge.³⁰

Previous research shows that specific sociodemographic characteristics are associated with those who smoke longer rod cigarettes: those who are black rather than white, those who are female rather than male, and those older in age.²⁶ We observed similar trends in our sample, except more frequent relighting behavior was not significantly associated with gender. We currently know that longer cigarettes may deliver more tar and nicotine than shorter length cigarettes³¹ and that there has been a recent increase in the manufacture of long cigarettes due to increased demand.²⁶ More research on relighting is needed to better explain these relationships and to inform tobacco product standards in regards to cigarette size and the long-term effects it may or may not have on those who relight, and more specifically, those who relight more or less frequently than others. Our study summarized biomarkers of smoking exposure and oxidative stress of relighters, which, to our knowledge, is the first of its kind. However, no significant biomarker trends were found with relighting frequency or status.

Limitations

The cigarette consumption data were self-reported and subject to potential recall bias. This analysis was a cross-section of baseline data, so no cause-effect relationship can be inferred. Our studies specifically recruited those with mood and anxiety disorders and those with less education, and therefore may not be representative of all smokers. Methods to divide relighting status behavior into further subgroups (infrequent relighters and frequent relighters) utilized an arbitrary cutoff value of relighting five cigarettes per pack of 20. This cut-point achieved a somewhat balanced observational sample size across the subgroups. However, given that the average number of cigarettes reportedly relit by those exhibiting relighting behavior was five cigarettes, we believe the arbitrary nature of this observational analysis to be reasonably justifiable. Regardless of these limitations, we found the characteristics and smoking behaviors of relighters were consistent with other findings.

Conclusions

Relighting is a common but underreported aspect of smoking behavior that should be investigated further and considered more in future studies. With the trend of increasing tobacco taxes in the United States and the possible unintended consequence of stimulating more smokers to re-light, it is important to consider the possible role of relighting with respect to the increasing cotinine uptake per cigarette over time, as reported by Jarvis et al.⁶

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Declaration of Interests

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