J Behav Med (2022) 45:124–132
https://doi.org/10.1007/s10865-021-00258-2

Longitudinal effects of cigarette pictorial warning labels among young adults

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Received: 23 April 2021 / Accepted: 8 September 2021 / Published online: 23 September 2021

Abstract Young adults are influenced by cigarette package marketing. Pictorial warning labels are a recommended intervention. Evidence demonstrates pictorial warnings impact negative emotion, risk perceptions, and motivation to quit smoking, but there is limited research on their effects over time. This study analyzes data from a randomized trial of young adult smokers (N = 229) exposed to a pictorial or text-only cigarette warning. We assessed changes in fear, anger, risk perceptions, and motivation to quit smoking after 4 weeks using latent change score modeling and over 3 months using latent growth modeling. Latent change results showed exposure was associated with increases in fear, anger, and motivation to quit after 4 weeks. Latent growth showed exposure was associated with increases in motivation to quit smoking over 3 months, but not other outcomes. Findings suggest pictorial warning labels produce an emotional response and increase motivation to quit among young adult smokers.

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Keywords Cigarettes · Addiction · Prevention · Public health · Marketing · Tobacco Control

Introduction

Cigarette smoking is the leading preventable cause of death in the U.S., accounting for 30% of all cancer cases and incurring upwards of $300 billion in costs to society each year (U.S. Department of Health & Human Services, 2014). Cigarettes are currently one of the most commonly used tobacco products among U.S. young adults, with roughly 8% smoking "some days" or "every day" in 2019 (Cornelius et al., 2020; Creamer et al., 2019). Young adults have the lowest quit rates of all adult age groups (Jamal et al., 2015) and this is a vulnerable developmental period when smoking behaviors are often solidified (Berg et al., 2018; Brook et al., 2008; Villanti et al., 2019).

Marketing is one prominent way in which cigarettes appeal to potential and current consumers (U.S. Department of Health & Human Services, 2014). Cigarette packaging is a major marketing tool for tobacco companies, and smokers are regularly exposed to cigarette packages (U.S. Department of Health & Human Services, 2012). To offset the promoting influence of cigarette packaging, pictorial warning labels communicating the risks of smoking on cigarette packs through text and visual imagery are recommended as part of a suite of comprehensive tobacco control interventions (Centers for Disease Control & Prevention, 2014). Estimates indicate implementing pictorial warnings in the U.S. would prevent a projected 650,000 smoking-attributable deaths (Levy et al., 2017).

In 2011, the FDA issued a rule requiring pictorial warnings to replace existing text-only warnings (Food & Drug Administration, 2011). Legal challenges succeeded

in delaying implementation of pictorial warnings in part because greater empirical evidence was needed to justify the warnings' graphic nature to communicate well-known risks (Public Health and Tobacco Policy Center, n.d.; Public Health Law Center, 2011). Since this time, research has aimed to address questions raised in legal challenges surrounding their effectiveness and causal mechanisms leading to cessation, including studies examining the impact of pictorial warnings over time on outcomes like negative emotion, risk perceptions, and motivation to quit smoking (Brewer et al., 2019; Hall et al., 2018; Noar et al., 2016). This evidence informed a new rule with an implementation date of 2022 with pictorial warnings communicating lesser known risks of smoking (Food & Drug Administration, 2020, 2021). Pictorial warnings' effects on negative emotions, such as fear, has shown to be a mechanism through which they promote cessation (Noar et al., 2016). There is mixed evidence as to whether pictorial warnings influence risk perceptions (Brewer et al., 2019; Hall et al., 2018). Yet studies have demonstrated pictorial warnings labels are effective for motivating smokers to quit and promoting quit attempts (Brewer et al., 2019; Evans et al., 2015; Hammond, 2011; World Health Organization Framework Convention on Tobacco Control, 2003). Studying these outcomes over time is important due to evidence of warning "wear out" (i.e., diminished effects with repeated exposures) and calls to better understand trajectories of outcomes after exposure to a pictorial warning, especially among young people (Thrasher et al., 2019).

Despite some evidence of pictorial warnings' effectiveness, there is limited research on the effects on negative emotion, risk perceptions, or motivation to quit over time after exposure to a pictorial warning (Brewer et al., 2016; Parada et al., 2018; van Mourik et al., 2020). One large clinical trial assessed trajectories of these outcomes during a 4 week intervention period in adults (Parada et al., 2018). Results demonstrated increases in quit intentions for those in a pictorial warning condition, but this effect was not sustained over time. Results also showed that fear and other negative affective responses significantly decreased after exposure to a pictorial warning over time. However, this work focused on mean differences by condition, time, and condition by time independently. It is important to consider such factors simultaneously and extend this work to understand the impact on outcomes after a 4 week intervention period. With calls to better understand trajectories of outcomes (Thrasher et al., 2019) and impending regulations (Food & Drug Administration, 2020), studying the longitudinal impact of pictorial warnings on negative emotions, risk perceptions, and motivation to quit is warranted.

It is unclear how negative emotion, risk perceptions, and motivation to quit function longitudinally after exposure to a pictorial warning. There is also little information about how these trajectories function among young adults. The current study seeks to examine the longitudinal effects of pictorial warnings among young adults. Like prior studies, we assessed change in these outcomes after a 4 week exposure to a pictorial warning. We also extended this by examining the longitudinal effects over a 3 month period on negative emotion, risk perceptions, and motivation to quit smoking. We hypothesized that exposure to a pictorial warning label will be associated with greater emotional response, risk perception, and motivation to quit smoking and that these effects will wane over time without repeated exposure.

Methods

Sampling & Design

This study was a secondary analysis of data from a prospective randomized trial to pictorial cigarette warning labels among young adult smokers ages 18–30 (NCT03446170). Participants for the randomized trial were recruited from the Washington, DC community using flyers, social media, newspaper advertisements, online classifieds, by re-contacting participants in prior studies, and direct referrals. Study eligibility criteria included: (1) 18–30 years; (2) smoking ≥ 100 lifetime cigarettes; (3) currently smoking cigarettes every day or some days (4) willing to send and receive text messages via a personal mobile phone; and (5) able to complete all study assessments and procedures in English. Interested participants who contacted the research team in response to study advertisements were screened for eligibility by telephone. Eligible, interested participants provided informed consent by mail to complete enrollment. The study protocol was approved by the host institution's institutional review board.

The study procedures first included an online baseline assessment, followed by an in-person visit. During the visit, participants were randomized to one of five conditions for a 4 week period, including (1) gain-framed branded pack, (2) loss-framed branded pack, (3) gain-framed plain pack, (4) loss-framed plain pack, or a (5) control pack. Those randomized to one of the first four conditions were then randomized to receive pictorial warnings communicating the risks of (1) cancer, (2) lung disease, (3) heart disease/stroke, or (4) mortality informed by prior work (Mays et al., 2014, 2015). Participants in the pictorial warning conditions were provided with high-resolution labels to affix to their packs. Pictorial warnings covered 50% of the front and back of the cigarette package as outlined in FDA's finalized rule. Participants were provided with additional warnings for cigarettes purchased after the visit and could contact study staff at any time for additional labels. Participants in the control condition used their usual brand pack with the existing Surgeon

General text only warning. During the 4-week period, participants responded to text messages sent to their mobile phones asking them to respond with a picture of their cigarette pack as a measure of protocol adherence. Participants were also instructed to stop using the intervention labels after the 4 week period. Follow-up assessments were administered online immediately post-intervention, 1 month, and 3 months later. For the current study, there were minimal differences in study outcomes between the individual pictorial warnings and the control condition and no differences between warning types, so we combined participants in the four pictorial warning conditions and compared their outcomes to the text-only warning exposure condition. The data supporting this approach are presented in the Supplemental Materials.

Measures

Demographics & Smoking Status We assessed demographic characteristics including age, gender, race, ethnicity, education level, and gross annual income at baseline (Chowdhury et al., 2010). Cigarette smoking status was assessed at eligibility screening by asking two validated questions including (1) smoking ≥ 100 lifetime cigarettes and (2) currently smoking cigarettes every day or some days (Berkman et al., 2011; Song & Ling, 2011; Song et al., 2007). Additionally participants were asked, "During the past 7 days, on how many days did you smoke one or more cigarettes?" at baseline. We characterized participants as daily (7 days) v. non-daily (0–6 days) smokers. Participants were asked if they were currently aware of pictorial warning labels at baseline. Lastly, adherence was calculated by summing the number of days individuals responded to messages during the 4 week intervention period (yes = 1, no = 0) and then this score was averaged.

Emotional Response Emotional response included six items ranging from 1 = Not at All to 7 = Very Much and was measured at all time points (Kees et al., 2010). The question stem asked, "*Thinking about the warning labels you may have seen on cigarette packs, how much do these warnings make you feel…"* This included items asking participants if they felt scared, fearful, nervous, irritated, angry, and annoyed. We used two factors, fear (scared, fearful, nervous; $\alpha = 0.94$) and anger (irritated, angry, and annoyed; $\alpha = 0.93$). Fear and anger items were averaged for use in multivariable analyses. Fear and anger items were loaded onto independent latent constructs in multivariate analyses.

Risk Perceptions Risk perceptions included four items ($\alpha = 0.71$) ranging from 1 = Not at All to 5 = Very Much and was measured at all time points (Lipkus et al., 2011; Wong & Cappella, 2009). This included both deliberative and affective risk perceptions, each with two items. A sample deliberative risk perceptions item asked, "*How much do you think your health has been harmed by smoking?*" A sample affective risk perceptions items asked, "*How concerned are you that your smoking has affected your health?*" All risk perception items were averaged for use in multivariable analyses and were loaded onto one latent construct in multivariate analyses.

Motivation to Quit Smoking Motivation to quit smoking cigarettes was measured at all time points with four items with responses ranging from 1 = Definitely Will Not to 4 = Definitely Will ($\alpha = 0.76$) (Berkman et al., 2011; Schneider et al., 2012). The question stem asked, "*In the next 3 months, how likely is it that you will…*" 1. Quit smoking completely?; 2. Reduce the number of cigarettes you smoke?; 3. Refrain from smoking in the near future?; and 4. Talk to a friend, family member, or spouse/partner about quitting smoking? All motivation to quit smoking items were averaged for use in multivariable analyses and were loaded onto one latent construct in multivariate analyses.

Analyses

We used descriptive statistics to characterize the sample and we analyzed outcomes in pictorial warning label vs. no pictorial warning label conditions using multivariable ANCOVAs controlling for baseline and study design (cigarette pack type and adherence) covariates. We assessed change during the 4 week exposure period using a latent change score model for each outcome of interest – fear, anger, risk perceptions, and motivation to quit smoking (Geiser, 2013; McArdle, 2009). We also examined effects over time after pictorial warning label exposure using a latent growth model for each outcome.

Multivariate latent change score and latent growth analyses techniques were chosen to minimize measurement error in our results. We used best practices for latent modeling techniques with Mplus Version 7.4 (B. Muthén & Asparouhov, 2009; L. K. Muthén & Muthén, 2010). We used standard indices to evaluate model fit for measurement and structural models: the Chi Square test of model fit greater than 0.05, Root Mean Squared Error of Approximation (RMSEA) less than 0.05, Standardized Root Mean Square Residual (SRMR) less than 0.08, and the Comparative Fit Index (CFI) above 0.90 (Brown, 2015; Geiser, 2013). We assessed multiple indices for a holistic assessment of model fit provided the Chi Square test of model fit can be sensitive to sample size. We reviewed indices for each step of the measurement model building process (e.g., for each latent factor and combined) and for each structural model.

Latent Change Score Modeling We constructed each latent change score model in the same fashion. For instance, motivation to quit items were each loaded onto a latent construct for baseline and post-intervention and the model includes the change score between the two time points

represented as a latent construct (latent Δ) (Geiser, 2013; McArdle, 2009). This approach uses individual change scores as opposed to averages while accounting for measurement error. The structural model tested the effects of pictorial warnings on the change score by regressing it onto a manifest variable for randomization condition (0 = text only warning, 1 = pictorial warning). This modeling approach follows prior work (Howe et al., 2015, 2017), and we followed these steps for each outcome.

Latent Growth Modeling We used similar systematic steps for the latent growth models. For instance, motivation to quit items were loaded onto a latent construct for each time point, including post-intervention, 1 month, and 3 months (Geiser, 2013). The structural model tested the effects of pictorial warnings on the slope by regressing it onto a manifest variable for randomization condition (0 = text only warning, 1 = pictorial warning). Like the latent change models, we created a separate model for each outcome using these steps.

For latent change score and latent growth models, we used sensitivity analyses to examine cross-time correlated errors for each item, determining that setting parameters to be equal across time was optimal. For both sets of analyses, covariates were regressed onto the change score and slope. Additional details about modeling specifications are in the Supplemental Materials. Although retention across time points was high, we used full information maximum likelihood to address data missing at random and bootstrapping to estimate confidence intervals. We report unstandardized coefficient estimates and 95% confidence intervals (CI). Parameters that do not contain zero are statistically significantly different from zero.

Results

The sample included 229 eligible, consenting participants. Table 1 shows that the sample averaged about 25 (SD = 3.4) years of age, was a majority male (n = 126, 55%), non-White (n = 121, 53%), and non-Hispanic (n = 206, 90%). Close to half of the sample had a college education or more (n = 106, 46%), but also had less than $35,000 gross annual income (n = 118, 52%). A majority of participants (n = 146, 63.8%) reported smoking daily in the past week. Less than half (n = 92, 40%) were not aware of pictorial warnings prior to the study. Participants responded to mobile messages on average 21.1 of 28 days, corresponding to 75% adherence. We found no differences between conditions for variables in Table 1.

Retention was ≥ 90% at all time points: baseline (n = 229), post-intervention (n = 211, 92% retention), 1 month (n = 206, 90% retention), and 3 months (n = 209, 91% retention). There were no significant differences between those lost to follow-up and those retained (Table 1), except those lost to follow-up had lower adherence ($p < 0.001$).

Table 1 Sample Baseline Characteristics (N = 229)

	M (SD)	n (%)
Age	24.6 (3.4)	–
Gender		
Female	–	102 (44.5)
Male	–	126 (55.0)
Race		
White	–	106 (46.3)
Non-White	–	121 (52.8)
Hispanic		
Yes	–	22 (9.6)
No	–	206 (90.0)
Education		
Some college or less	–	123 (53.7)
College grad or more	–	106 (46.3)
Income less than $35,000		
Yes	–	118 (51.5)
No	–	109 (47.6)
Past 7 Day Cigarette Smoking		
Nondaily (0–6 Days)	–	83 (36.2%)
Daily (7 Days)	–	146 (63.8%)
Awareness of pictorial warnings		
Yes	–	137 (59.8)
No	–	92 (40.2)
Adherence (average days)	21.1 (7.6)	–

Multivariable Analyses

Table 2 shows mean levels for each outcome by each time point, controlling for covariates. Mean fear responses were significantly higher among those exposed to a pictorial warning label at post-intervention ($p < 0.001$), 1 month ($p < 0.01$), and 3 months ($p = 0.01$). Mean anger was significantly higher among those exposed to a pictorial warning label at 3 months ($p = 0.03$). There were no significant mean differences between the text only warning and pictorial warning conditions for risk perceptions. Mean motivation to quit was higher for those pictorial warning condition at post-intervention ($p < 0.01$), 1 month ($p < 0.01$), and 3 months ($p = 0.01$).

Multivariate Analyses

Measurement Models For both latent change score and latent growth models, fit was within acceptable ranges across the indices for each construct. However, the models for risk perception had the least optimal fit. The Supplemental Materials provide full details on the measurement model and

Table 2 ANCOVA Results

Outcome	Baseline LSM (SE)	Post-Intervention LSM (SE)	1 Month LSM (SE)	3 Months LSM (SE)
Fear				
Text only warning	2.9 (0.3)	**2.6 (0.3)**	**2.7 (0.3)**	**3.0 (0.3)**
Pictorial warning	2.9 (0.1)	**3.7 (0.1)**	**3.6 (0.1)**	**3.8 (0.1)**
Anger				
Text only warning	2.7 (0.3)	2.6 (0.3)	2.4 (0.3)	**2.5 (0.3)**
Pictorial warning	2.5 (0.1)	3.1 (0.1)	2.9 (0.1)	**3.2 (0.1)**
Risk Perceptions				
Text only warning	3.3 (0.1)	3.4 (0.1)	3.4 (0.1)	3.3 (0.1)
Pictorial warning	3.3 (0.1)	3.4 (0.1)	3.4 (0.1)	3.5 (0.1)
Motivation to Quit				
Text only warning	2.4 (0.0)	**2.4 (0.1)**	**2.4 (0.1)**	**2.5 (0.1)**
Pictorial warning	2.4 (0.0)	**2.7 (0.0)**	**2.8 (0.0)**	**2.8 (0.0)**

Least Squared Mean (Standard Error). Covariates include baseline measures for each follow-up model, respectively, as well as design elements. Bolded output highlights statistical significance at $p < 0.05$

unconditional estimates for each outcome. Invariance testing indicated that it was most appropriate to set the loadings for each factor to be equal across time points. As expected, models also violated assumptions of conditional independence across time. Consequently, item cross-time correlations were added to improve measurement model fit for each model.

Latent Change Score Models Table 3 shows structural model fit indices and results for latent change score models. Results indicate there was significant change from baseline to post-intervention in the expected direction for fear (B = 1.05, 95% CI = 0.50, 1.55), anger (B = 0.55, 95% CI = 0.02, 1.07), and motivation to quit (B = 0.28, 95% CI = 0.05, 0.51) among participants exposed to a pictorial warning. There was no significant change from baseline to post-intervention for risk perceptions (B = 0.09, 95% CI = -– 0.08, 0.23).

Latent Growth Models Table 4 shows the structural fit indices and results for the latent growth models. Results indicate that exposure to a pictorial warning label was associated with a positive, linear slope over time for motivation to quit smoking (B = 0.08, 95% CI = 0.01, 0.16). For all other outcomes – fear, anger, and risk perceptions – exposure to a pictorial warning was not significantly associated with change over time.

Discussion

This study examined the longitudinal effects of pictorial warnings on cigarette packages among young adults. We assessed initial change after a 4 week exposure period to a pictorial warning with latent change score models, results of which indicate pictorial warning labels produced change in fear, anger, and motivation to quit from baseline to post-intervention. We also examined the prospective effects of fear, anger, risk perceptions, and motivation to quit smoking over the 3 month follow-up with latent growth modeling. As hypothesized, exposure to a pictorial warning was not significantly associated with increases in fear, anger, and risk perceptions over time, but it was associated with increases in

Table 3 Latent Change Model Results

	Structural Model Fit				Pictorial Warning—> Latent Δ
Outcome	χ^2 p value	CFI	RMSEA	SRMR	Coefficient (95% CI)
Fear	0.93	1.00	0.02	0.00	**1.05 (0.50, 1.55)**
Anger	0.04	0.99	0.05	0.06	**0.55 (0.02, 1.07)**
Risk Perceptions	0.17	0.99	0.03	0.04	0.09 (-0.08, 0.23)
Motivation to Quit	0.09	0.99	0.04	0.06	**0.28 (0.05, 0.51)**

χ^2 p value = Chi Square test of model fit test, CFI = Comparative Fit Index, RMSEA = Root Mean Squared Error of Approximation, SRMR = Standardized Root Mean Square Residual. Results include unstandardized estimates with 95% Confidence Intervals (CI). Bolded output highlights statistical significance

Table 4 Latent growth model results

Outcome	Structural Model Fit				Pictorial Warning—> Slope
	χ^2 p value	CFI	RMSEA	SRMR	Coefficient (95% CI)
Fear	< 0.001	0.99	0.04	0.05	0.06 (−0.12, 0.25)
Anger	< 0.001	0.99	0.04	0.04	0.09 (-0.10, 0.27)
Risk Perceptions	< 0.001	0.87	0.10	0.07	0.02 (−0.02, 0.07)
Motivation to Quit	< 0.001	0.97	0.05	0.05	**0.08 (0.01, 0.16)**

χ^2 p value = Chi Square test of model fit test, CFI = Comparative Fit Index, RMSEA = Root Mean Squared Error of Approximation, SRMR = Standardized Root Mean Square Residual. Results include unstandardized estimates with 95% Confidence Intervals (CI). Bolded output highlights statistical significance

motivation to quit over time for 3 months after the exposure finished.

The study results indicate three primary findings. First, the multivariable models showed that pictorial warnings produced changes in fear and motivation to quit post-intervention. Yet, the latent change score models show there were changes in fear, anger, and motivation to quit. This modeling technique could be leveraged to subsequently determine what mediates the changes in motivation to quit. Other extensions should seek to model other tobacco-related outcomes longitudinally such as smoking behavior and topography. Additionally, latent growth modeling allowed us to examine trajectories of change in outcomes over time. This modeling approach is useful to minimize measurement error and, in future studies, can advance our understanding of pictorial warning exposure effects over time.

Second, pictorial warning exposure was associated with the slope for motivation to quit smoking. This was an unexpected result considering the pictorial warning condition did not have continued or repeated exposure after 4 weeks (Lochbuehler et al., 2019). However, this demonstrates that young adults may be particularly sensitive to heuristic cues used in pictorial warnings and that their effects can be sustained following the exposure. These effects were not seen in the other outcomes such as fear, anger, and risk perceptions. The lack of waning for the outcomes of interest over the 3 month follow-up period suggests that the pictorial warning labels were effective in providing a sustained effect in the short-term. It cannot, however, be ruled out that the other constructs did not change. It may be that change was non-linear, and therefore not detected in the current models, but should be done in future work with the availability of additional time points (Brown, 2015; Geiser, 2013). Additionally, despite the multivariable results showing mean differences for fear by condition at each time point, the multivariate analyses did not demonstrate the pictorial warning exposure predicted increased fear over time. Thus, there is change in fear over time that was not fully explained, perhaps due to other characteristics not measured here, such as personality variables (Reyna & Rivers, 2008). In the future, it will be important to examine how changes in emotional response such as fear to pictorial warnings relate to motivation to quit, and whether individual-level (e.g., personality) or other factors account for the observed patterns over time.

Third, exposure to pictorial warning labels was associated with greater mean levels of fear, anger, and motivation to quit smoking post-intervention. However, results indicated that at post-intervention and longitudinally that risk perceptions did not change. Risk perceptions are cognitions that influence behavior in several theories (Fishbein & Ajzen, 2010; Janz & Becker, 1984; Slovic, 1987) and it is perhaps unusual that they did not increase alongside motivation to quit. Yet, in the case of pictorial warnings, the literature has been mixed (Brewer et al., 2019; Hall et al., 2018). The current study demonstrated risk perceptions may have had a ceiling effect with relatively high mean levels at baseline, indicating perhaps a one-tailed hypothesis test could be suitable in the future. Additionally, risk perceptions had the least suitable latent model fit in multivariate analyses. It may be that better specification of risk perceptions measures are needed, including discrete risk perceptions (e.g., affective, deliberative) (Ferrer et al., 2016; Kaufman et al., 2019, 2020; Skurka et al., 2019). Future work should investigate the role of discrete risk perceptions in motivating cessation in response to pictorial warnings. For instance, it may be useful to consider such findings for policy-relevant outcomes for regulations put forth in FDA's recently finalized rule (Food & Drug Administration, 2020). This includes studying the effects of risk perceptions for lesser-known health consequences of smoking.

The study results should be interpreted in light of its limitations. The study did not test the effects of a pictorial warning on smoking behavior or examine the influence of factors such as nicotine dependence. Future work can apply similar modeling approaches to those used here for behavioral outcomes as well as test variations on directionality of the emotional response measures. For instance, it could be that pictorial warning label exposure led to anger directed toward

the tobacco industry as opposed to the warning itself. Additionally, changes in outcomes may have been non-linear, and sample size may have limited statistical power to detect smaller effects. Lastly, the study used a convenience sample of young adult smokers, which may limit generalizability.

This study demonstrated pictorial warnings were associated with change in fear, anger, and motivation to quit from baseline to post-intervention among young adults. Future work should understand what factors are associated with and mediate increases in motivation to quit after exposure. This affords an opportunity to address specific aspects of the legal challenges and bolster impending regulations (Food & Drug Administration, 2020). Future studies could also build from this work to study dose–response effects for various pictorial warnings from the 2020 rule among a diverse, population-based sample as well. Studying these effects can also assist to better understand pictorial warnings' effects among a vulnerable young adult population and has potential to support warning implementation and improve the health of the public.

Acknowledgements The authors would like to acknowledge George W. Howe, PhD and Andrea C. Villanti, PhD, MPH for their feedback on earlier versions of the manuscript. The authors would also like to acknowledge study participants and research staff for their efforts in data collection and follow-up procedures.

Authors' contributions ACJ led the current study conception and design with input from DM, MMT, and SJS. DM led the parent study conception, design, and data collection. ACJ conducted formal data analyses with support from SJS. ACJ wrote the first draft of the manuscript. All authors read the manuscript, provided input, and approved the final manuscript. ACJ, DM, and AAS led funding acquisition.

Funding Research reported in this publication was supported by the National Cancer Institute (NCI) of the National Institutes of Health (NIH) under Award Number F31CA239567. Research reported in this publication was also supported by the NCI of the NIH and the U.S. Food and Drug Administration (FDA) Center for Tobacco Products under Award Number K07CA172217 and U54CA229973. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH or the FDA.

Declarations

Conflict of interest The authors have no conflicts of interest to declare.

Ethical approval The study complies with ethical standards for the protection of human subjects. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the Georgetown University Institutional Review Board. The study is registered as NCT03446170 at clinicaltrials.gov.

Consent to participate Written informed consent was obtained from all individual participants included in the study.

Consent for publication Not applicable.

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