



Published in final edited form as:

Addict Behav. 2025 August ; 167: 108354. doi:10.1016/j.addbeh.2025.108354.

Exploring relationships among smoking cessation app use, smoking behavioral outcomes, and pharmacotherapy utilization among individuals who smoke cigarettes

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Abstract

Introduction: Most individuals who smoke cigarettes are interested in quitting, but many are unable to quit. Fewer than one-third of individuals who smoke cigarettes attempt to quit using FDA-approved cessation methods, such as nicotine replacement therapy (NRT) and prescription medications. Smoking cessation apps (SCAs) provide individuals with personalized quit plans, information about smoking cessation treatments, craving management strategies, and other features. However, their relationship to NRT/prescription medication utilization and quit attempts is understudied.

Methods: We conducted a longitudinal secondary data analysis using a subset of adults who smoked at least 100 cigarettes in their lifetime, currently smoked every day or some days, and planned to quit within a year. This subset was drawn from the Population Assessment of Tobacco and Health (PATH) Study, a nationally representative cohort study. We utilized Generalizing Estimating Equation models to examine the longitudinal associations between SCA use initiation and the following outcomes across 2014–2019: NRT, prescription medications, and quit attempts.

Results: SCA use initiation was associated with greater odds of prescription medication utilization (AOR = 2.43, 95 % CI: 1.63, 3.64; $p < 0.05$). Likewise, SCA use initiation was

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Schuyler C. Lawson: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Karin Kasza:** Writing – review & editing, Supervision, Methodology, Conceptualization. **R.Lorraine Collins:** Writing – review & editing, Supervision, Conceptualization. **Richard J. O'Connor:** Data curation. **Gregory G. Homish:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization.

Ethics approval

This study was classified as “Not Human Research” by the University at Buffalo Institutional Review Board (STUDY00006947). The data were not collected by the authors and were deidentified when extracted from a publicly available online source.

associated with greater odds of making a quit attempt (AOR = 1.38, 95 % CI: 1.09, 1.76; $p < 0.01$), but not NRT utilization.

Conclusion: Among adults who regularly smoked cigarettes and had plans to quit, SCA use initiation was associated with prescription medication utilization and quit attempts but not NRT utilization. SCAs may have utility as a population-level intervention but specific features needed to be studied further.

Keywords

Smoking cessation apps; NRT; Prescription medications; PATH; Longitudinal

1. Introduction

Despite decades of declining smoking prevalence since the landmark publication of the 1964 Surgeon General's report, smoking continues to be the leading cause of preventable death in the United States (HHS, 2020). It is estimated that approximately 480,000 deaths per year are attributable to cigarette smoking and secondhand smoke exposure (HHS, 2020; Rostron, 2013). Over a third of those deaths are people with mental illnesses, who tend to have a high prevalence of smoking relative to the general population (Prochaska et al., 2017). According to the Surgeon General's Office, the economic toll of cigarette smoking exceeds \$170 billion in the United States each year (HHS, 2020).

Most individuals who smoke are interested in quitting (Babb et al., 2017). Still, fewer than one-third of individuals who smoke cigarettes attempt to quit using FDA-approved smoking cessation pharmacotherapies (e.g., nicotine replacement therapy and prescription medications) (Babb et al., 2017; HHS, 2020). Notably, the most common quitting method is 'cold turkey' (i.e., unaided quit attempts), even though fewer than one in 10 individuals who smoke achieve smoking cessation (i.e., having discontinued smoking for one day or longer with the intention of quitting; (Babb et al., 2017; HHS, 2020). This is worrisome because smoking cessation confers health benefits to all individuals who smoke, regardless of age (HHS, 2020). Furthermore, the underutilization of FDA-approved smoking cessation pharmacotherapies is inconsistent with the US Public Health Service's Clinical Practice Guideline on Treating Tobacco Use and Dependence, which recommends improving smoking cessation rates via evidence-based treatment modalities (Fiore et al., 2008; HHS, 2020). While substantial evidence suggests these smoking cessation medications are associated with increasing quit rates in individuals who smoke, bolstering their utilization remains an unrealized public health goal (Cox et al., 2011; HHS, 2020; Schlam & Baker, 2013). From a health equity standpoint, this is also concerning given that the rates of smoking cessation pharmacotherapy utilization are even lower among people from marginalized populations, such as African Americans, Hispanic/Latinx Americans, and American Indians/Alaska Natives relative to White Americans due to factors such as financial barriers and medical mistrust (Fu et al., 2007; Fu et al., 2008; Fu et al., 2014; Fu et al., 2005; Scharff et al., 2010). Consequently, these populations experience disproportionately higher rates of smoking-related morbidity and mortality relative to White Americans (Agaku et al., 2020; Braveman et al., 2010; Gone & Trimble, 2012; HHS, 2020; Martell et al., 2016; Mowery et al., 2015).

Smoking cessation apps (SCAs) are computer programs available on mobile devices, such as tablets and smartphones, designed to aid in smoking cessation (Abroms et al., 2013). SCAs are heterogeneous, variously incorporating features such as cigarette trackers, geofencing, educational materials, behavioral therapies, and gamification to maintain smoking cessation progress (Abroms et al., 2013; Abroms et al., 2011; Portelli et al., 2022; Robinson et al., 2020; Seo et al., 2022). Specifically, 29 % of SCAs are only informational (i.e., similar to an electronic book or e-Book), 30 % are multifunctional (i.e., they have assistive features to facilitate smoking cessation), and 42 % are a combination of informational and multifunctional (Seo et al., 2022).

In the past decade, there has been an influx of SCAs in the marketplace (Abroms et al., 2013; Abroms et al., 2011; Seo et al., 2022). As of 2020, over one hundred SCAs were available in the Google Play and iPhone App Stores (Seo et al., 2022); 62 % were free, 24 % were initially free with in-app purchases for additional features, and 14 % required upfront payment (Seo et al., 2022). In addition to the commercial options, the National Cancer Institute created two free SCAs (QuitGuide and quitSTART) integrated with their [Smokefree.gov](https://www.smokefree.gov) initiative (Prutzman et al., 2021). SCAs are a potentially accessible method of disseminating smoking cessation interventions at the population level, given that American smartphone usage is increasingly commonplace (Heffner & Mull, 2017; Smith et al., 2015).

Feasibility/pilot studies of specific SCAs have shown high ratings in usability, acceptability, engagement, and likability (Bricker et al., 2017; Gowarty et al., 2021; Iacoviello et al., 2017; Marler et al., 2019). However, randomized clinical trial (RCT) data regarding the association between SCA utilization and smoking abstinence are mixed. Some studies noted higher rates of smoking abstinence relative to various comparators (e.g., usual care, self-help booklets, web-based interventions, other apps, smoking cessation counseling, or placebos that lack functionality) (BinDhim et al., 2018; Bricker et al., 2022; Bricker et al., 2020; Carrasco-Hernandez et al., 2020; Houston et al., 2022; Masaki et al., 2020; Webb et al., 2022), whereas other studies did not find any significant differences (Affret et al., 2020; Baskerville et al., 2018; Etter & Khazaal, 2022; Garrison et al., 2020). A recent systematic review/meta-analysis of 9 RCTs conducted between 2017 and 2023, which were described as high-quality by Guo and colleagues (2023), did not support the effectiveness of SCAs as standalone interventions. Still, it noted that their effectiveness was augmented when used with pharmacotherapies (Guo et al., 2023). Specifically, participants using SCAs with pharmacotherapy (3 studies, N = 1342) reported greater rates of smoking abstinence relative to participants who only received pharmacotherapy. SCAs have the potential to be utilized as a population-level intervention, but a lack of population-level studies limits the current literature. Population-level studies are important to consider given that RCTs tend to be limited by samples that are not always generalizable due to stringent eligibility criteria and other barriers that prevent underrepresented populations from enrolling in the studies (King et al., 2011; Scharff et al., 2010; Webb Hooper et al., 2019). This limitation must be addressed to more clearly understand if this type of intervention is applicable to the general population, especially people from marginalized populations. Furthermore, many apps available in the iPhone and Android marketplace remained unstudied.

Using population-level data, the present study aimed to examine relationships among SCA use initiation, pharmacotherapy utilization, and quit attempts longitudinally in individuals who regularly smoke cigarettes. The specific aims are to longitudinally examine, among individuals who regularly smoke cigarettes, the relationship between 1) SCA use initiation and NRT utilization, 2) SCA use initiation and prescription medication utilization, and 3) SCA use initiation and quit attempts.

2. Methods

2.1. Study design

The Population Assessment of Tobacco and Health (PATH) Study is a nationally representative, longitudinal cohort study of US adults (18 years and older) and youth (12–17 years old) designed to examine tobacco use and health to inform tobacco control policies (USDHHS, 2022). This study utilizes data from the publicly available Wave 2 (October 2014–October 2015), Wave 3 (October 2015–October 2016), Wave 4 (December 2016–January 2018), and Wave 5 (December 2018–November 2019) surveys from a weighted sample of 13,862 adult participants. The weighting is designed to account for different probabilities of non-response, selection, and possible limitations in the sampling frame (e.g., underrepresentation of certain populations). PATH Study participants were recruited using an address-based, area-probability sampling approach. This recruitment method also included using an in-person household screener to select adults from households that oversampled adult tobacco users, young adults, and African American adults. Sample weighting procedures were employed to adjust for oversampling and nonresponse, enabling estimates to be representative of the non-institutionalized civilian US population.

After obtaining participant consent, data were collected via Audio-Computer Assisted Self-Interviews provided in English or Spanish. The PATH Study protocol, methodological information, interviewing procedures, and response rates are available elsewhere: the Population Assessment of Tobacco and Health (PATH) Study Series (umich.edu) (Hyland et al., 2017; Tourangeau et al., 2019; United States Department of Health and Human Services, 2022). The University at Buffalo's Institutional Review Board approved the current analysis.

2.2. Participants

Our study used a subsample of participants from the PATH Study. These participants reported smoking 100 cigarettes in their lifetime, currently smoked every day or some days (i.e., smoking regularly), and indicated a plan to quit smoking/tobacco products within a year. Of the 13,862 available participants, our analysis sample included $n = 3,378$ individuals and $n = 12,409$ observations of those individuals across multiple waves. This sample also included individuals who used other types of tobacco products.

2.3. Independent variable

2.3.1. SCA use initiation: At Waves 2–5 (2014/2015–2018/2019), SCA use initiation was assessed by asking participants, “Have you ever used an app on your tablet computer or smartphone to help you quit using tobacco?”. This variable was recoded from a lifetime (i.e.,

ever use) variable to a dichotomous variable that captured the initiation of past 12-month use at each wave (i.e., never use vs. new past 12-month use).

2.4. Dependent variables

2.4.1. NRT utilization: At Wave 2 (2014/2015), all adult participants were asked, “In the past 12 months, have you used a nicotine patch, gum, inhaler, nasal spray, lozenge or pill?” to assess their NRT utilization. At Waves 3–5 (2015/2016–2018/2019), this question was limited to adult participants who used non-electronic tobacco products regularly, experimentally, or discontinued them recently. Also, the wording regarding “pill” use was removed from the PATH Study at Wave 5. Participants who did not receive this question were marked as missing or inapplicable and excluded from the analysis of the respective wave.

2.4.2. Prescription medication utilization: At Waves 2–5 (2014/2015, 2015/2016, 2016/2018/2018/2019), all adult participants who used non-electronic tobacco products and were past year quitters or quit attempters were asked, “Did you use Chantix, varenicline, Wellbutrin, Zyban, or bupropion to quit smoking/using tobacco products completely?” to assess their prescription medication utilization. Participants who did not receive this question were marked as a missing or “no” depending on if they met the criteria of our subsample (see section 2.2.).

2.4.3. Quit attempts: At Waves 2–5 (2014/2015–2018/2019), all adult participants who used tobacco products regularly (excluding e-cigarettes) were asked, “In the past 12 months, have you tried to quit [tobacco products/specific product]” to assess their quit attempts. This variable was recoded to also include individuals who recently quit smoking at follow-up.

2.5. Covariates

2.5.1. Race: At their baseline interview, participants were asked, “What is your race? Choose all that apply.” Due to our use of the publicly available dataset, the only racial categories included are Non-Hispanic Black, Non-Hispanic White, and Other. The other racial/ethnic groups in the “Other” category are available in the restricted dataset. We recoded this variable to include Hispanic participants by adding them to a new variable if they identified as Hispanic at the PATH Study baseline interview.

2.5.2. Sex: At their baseline interview, participants were asked, “What is your sex?” with the options being male or female.

2.5.3. Age: Participants’ age was a categorical variable derived from their baseline interview. The categories were the following: 18 to 24, 25 to 34, 35 to 44, 45 to 54, 55 to 64, 65 to 74, and 75 years old or older. At Wave 4, the 75 years or older category was removed from the PATH Study in favor of 65 or more years old. Due to the small sample sizes in those two categories, we transformed this variable into one with six age categories (18 to 24, 25 to 34, 35 to 44, 45 to 54, 55 to 64, and 65 years old or older).

2.5.4. Income: At Waves 2–5 (2014/2015–2018/2019), participants were asked, “Which of the following categories best describes your total household income in the past 12 months?” (Less than \$10,000, \$10,000 to \$24,999, \$25,000 to \$49,999, \$50,000 to \$99,999, and \$100,000 or more).

2.5.5. Nicotine Dependence: Participant nicotine dependence was assessed using a 16-item composite scale of questions from the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) measure for Impaired Control (American Psychiatric Association, 2013), the Nicotine Dependence Syndrome Scale (NDSS) (Shiffman et al., 2004), and the Wisconsin Inventory of Smoking Dependence Motives (WISDM) (Piper et al., 2004). This combined scale was developed in previous research to provide a validated standard instrument for measuring nicotine dependence among users of various tobacco products, with scores ranging from 15 to 76 (Strong et al., 2017). Participants received an average score at each wave, with higher scores indicative of higher nicotine dependence (Liu et al., 2017; Strong et al., 2017). To increase the interpretability of this continuous variable, we transformed it into a dichotomous variable in which scores less than or equal to the sample mean were classified as low nicotine dependence, and scores higher than the sample mean were classified as high nicotine dependence (Snell et al., 2021).

2.5.6. Mental health: internalizing problems: The Global Appraisal of Individual Needs assessed mental health problems – Short Screener (GAIN-SS), which was modified for the PATH Study (Dennis et al., 2006). This validated measure is used to identify individuals at risk for mental health and substance use disorders using a continuous measure of severity per the number of items endorsed. This study assessed internalizing problems (e.g., anxiety, depression, obsessive–compulsive disorder, and other disorders that involve high levels of negative affectivity) using 4-items. The reliability of the modified GAIN-SS subscales has been reported elsewhere (Conway et al., 2018). The number of responses endorsed for lifetime mental health problems was summed for each subscale. Complete data for subscale components were required with a range of 0–4. Participants were categorized into none/low symptoms (0–1), moderate symptoms (2–3), and high symptoms (4) to indicate their severity levels. Participants who endorsed high symptom severity levels indicated a high likelihood of a lifetime occurrence of a disorder with a need for treatment services (Dennis et al., 2006).

2.6. Statistical analyses

Generalized estimating equation (GEE) models were used to evaluate the primary outcomes. GEE models are ideal for evaluating correlated data from longitudinal analyses where repeated measures from the same individual are correlated (Muthén, 2006; Singer et al., 2003). Additionally, GEE models can examine various dependent variable outcomes such as continuous, binary, and count outcomes (e.g., Poisson, negative binomial) (Hardin & Hilbe, 2012). This statistical approach enables the inclusion of transitions from all three periods in a single analysis while statistically controlling for interdependence among observations contributed by the same individuals (Hardin & Hilbe, 2012; Liang & Zeger, 1986). We conducted GEE logistic regression models to evaluate SCA use initiation between baseline and follow-up and its association with treatment utilization and quit attempts assessed at

follow-up, W2-W3 (2014/2015–2015/2016), W3-W4, (2015/2016–2016/2017) and W4-W5 (2016/2018–2018/2019).

Each primary outcome was examined using three GEE logistic regression models: an unadjusted model, an adjusted model with sociodemographic covariates, and an adjusted model with sociodemographic and mental health covariates. These analyses included GEE logistic regression models with specified unstructured covariance, within-person correlation matrices, and binomial distribution of dependent variables using the logit link function. Analyses were weighted using the wave 5 “all waves” weights to produce nationally representative estimates, and variances were computed using the balanced repeated replication method with Fay’s adjustment set to 0.3 (Judkins, 1990). All analyses were conducted using Stata version 17 software (StataCorp., 2019). Demographic covariates (i.e., race, sex, age, and income) were included in each adjusted model. Estimates with a relative standard error > 30 or a denominator < 50 were suppressed since these estimates may provide unreliable precision.

3. Results

The sample was predominantly female (56 %), 25 to 34 years and 55 or older (24 % & 25 % respectively), non-Hispanic White (71 %), with incomes of \$10,000 to \$24,999 and \$25,000 to \$49,999 (27 % & 25 %), and high nicotine dependence (62 %). Overall, 4 % of the sample reported the initiation of SCA use. The descriptive characteristics of this sample are shown in Table 1.

3.1. Past 12-month NRT utilization as a function of SCA use initiation

We did not observe significant differences in NRT utilization between individuals who used SCAs compared to individuals who did not (Table 2). Results were consistent across the unadjusted and adjusted models.

3.2. Prescription medication utilization as a function of SCA use initiation

We observed that SCA users reported significantly greater odds of prescription medication utilization than individuals who did not use SCAs (AOR = 2.43, 95 % CI: 1.63, 3.64; $p < 0.05$). Results were consistent across the unadjusted and adjusted models (Table 3).

3.3. Past 12-month quit attempts as a function of SCA use initiation

We observed that SCA users reported significantly greater odds of past 12-month quit attempts than individuals who did not use SCAs (AOR = 1.38, 95 % CI: 1.09, 1.76; $p < 0.01$). Results were consistent across the unadjusted and adjusted models (Table 4).

4. Discussion

In the present study, we used data from the PATH Study to longitudinally examine the relationship between SCA use initiation, NRT utilization, prescription medication utilization, and quit attempts in individuals who regularly smoked cigarettes and planned to quit within a year. The results showed an association between past 12-month SCA use initiation and prescription medication utilization at follow-up. However, we did not

observe this relationship for past 12-month NRT utilization. Additionally, we observed an association between past 12-month SCA use initiation and past 12-month quit attempts at follow-up. Notably, these findings persisted even when controlling for socioeconomic status and internalizing mental health factors, both of which have a significant association with smoking. This study extends the literature by providing a longitudinal population-level analysis of SCAs.

Inconsistent with previous SCA studies, we did not observe an association between SCA use initiation and NRT utilization (Masaki et al., 2020; Webb et al., 2022). This is notable given that, unlike other studies focusing exclusively on the nicotine patch and gum, our study included all NRT modalities (Masaki et al., 2020; Webb et al., 2022). These discrepant findings may be attributable to whether some SCAs emphasized other treatment modalities instead of NRT (Abroms et al., 2013). Furthermore, some participants may have been skeptical of the effectiveness of NRT relative to prescription medications since the former contains nicotine, especially some racial/ethnic minority participants (Carpenter et al., 2011; Fu et al., 2007; Fu et al., 2008; Fu et al., 2014; Fu et al., 2005). This may partly explain why we observed an association between SCA use initiation and prescription medication utilization. These findings are consistent with the results of a previous longitudinal SCA study that examined the relationship between an SCA and varenicline utilization to see if it predicted smoking cessation (Carrasco-Hernandez et al., 2020). SCA users' prescription medication utilization may be related to the informational components of their respective apps, which dispel misconceptions about the commercially available medications. While SCAs cannot address the financial barriers that often prevent prescription medication utilization, they may contribute to less negative attitudes about their safety and effectiveness (HHS, 2020; Zeng et al., 2011). Given this potential explanation for the findings, SCAs may be a novel intervention for increasing positive attitudes about pharmacotherapies among marginalized populations, who have tended to underutilize them (Fu et al., 2007; Fu et al., 2008; Fu et al., 2005; HHS, 2020). Furthermore, the SCAs can be utilized to provide information about pharmacotherapies that are available for free via state-sponsored quitlines (Prutzman et al., 2021). However, there remains the need to study attitudes among marginalized populations regarding the efficacy and safety of SCAs as a smoking cessation intervention.

Overall, these findings partially correspond with the recent *meta*-analysis, which noted that combining SCAs and pharmacotherapies (i.e., NRT and prescription medications) may be more effective than standalone SCA utilization (Guo et al., 2023). Specifically, SCA users are likely to benefit from app features such as providing accurate and accessible information about pharmacotherapies, which leads to their utilization (Heffner et al., 2015; Hoepfner et al., 2015). Given that pharmacotherapies are heavily underutilized by individuals who smoke, SCAs may be a population-level intervention that merits further investigation. Furthermore, the informational components of SCAs may also be related to increased pharmacotherapy utilization by minoritized groups that have historically underutilized them due to systemic barriers as well as misconceptions about their effectiveness, but it may not be effectively addressing NRT misconceptions (Avila et al., 2022; Fagan et al., 2004; Fu et al., 2007; HHS, 2020).

Some studies have shown that smoking abstinence and quit attempts are linked to SCA utilization (Bricker et al., 2020; Carrasco-Hernandez et al., 2020; Danaher et al., 2019; Houston et al., 2022; Masaki et al., 2020; Webb et al., 2022). However, systematic review/*meta-analysis* research suggest this relationship may depend on the inclusion of pharmacotherapies (Guo et al., 2023). Our study, however, supports that notion of using SCAs as a standalone intervention is associated with quit attempts in individuals who regularly smoked cigarettes, regardless of their race/ethnicity, sex, or mental health status. Furthermore, earlier research has noted that using an acceptance and commitment therapy-based SCA was associated with higher odds of quitting smoking relative to a comparator app, even in marginalized groups (e.g., Black, Hispanic/Latinx, and low-income adults) (Hayes et al., 2009; Santiago-Torres, Mull, Sullivan, Kendzor, et al., 2022; Santiago-Torres, Mull, Sullivan, Zvolensky, et al., 2022; Santiago-Torres et al., 2022). However, some studies have not found differences in smoking abstinence rates or quit attempts between an SCA group and a control group (Affret et al., 2020; Baskerville et al., 2018; Etter & Khazaal, 2022; Garrison et al., 2020). The discrepancies in results could be due to differences in the study's sample characteristics, SCA type examined, or study duration. Our study used data from a nationally representative cohort study, while three of the four studies just mentioned (Baskerville et al., 2018; Etter & Khazaal, 2022; Garrison et al., 2020) did not use nationally representative samples. The study that included a nationally representative sample (Affret et al., 2020) was conducted in France, which has a different tobacco regulatory environment than the United States. Additionally, the four other studies (Affret et al., 2020; Baskerville et al., 2018; Etter & Khazaal, 2022; Garrison et al., 2020) each focused on a specific type of SCA, whereas our study examined all types of SCAs. Finally, our study had a longer timeframe than these four RCT studies due to the prospective cohort design of the PATH Study (Affret et al., 2020; Baskerville et al., 2018; Etter & Khazaal, 2022; Garrison et al., 2020; Hyland et al., 2017).

5. Strengths and limitations

Our study had several noteworthy strengths. To our knowledge, it is the first study to investigate use of SCAs in a nationally representative sample from the United States. Many studies on SCAs tend to have small sample sizes of minoritized participants, whereas our study had a substantial number of such participants. Moreover, the study was bolstered by a longitudinal design that spanned five years. Another aspect of our study that differed from the existing literature is that we evaluated SCAs more broadly instead of focusing on a specific type, making our findings more applicable to the real-world experiences of SCA users.

Along with the strengths, we also note some limitations of the present study. We measured past 12-month SCA use initiation without posing any specific questions about the type of SCAs used by the participants. Therefore, we cannot determine what types of SCAs, such as cognitive-behavioral therapy-based, acceptance and commitment therapy-based, and others, are driving the relationship between the primary outcomes. This limitation is notable because many commercially available SCAs are not supported by scientific data, thus raising concerns about their efficacy. (Abroms et al., 2013; Heffner et al., 2015). Additionally, there is the possibility that some participants may be unknowingly using pro-tobacco apps

developed by the tobacco industry (BinDhim et al., 2014, 2015). Another limitation of our study is that it only focused on individuals who regularly smoked cigarettes and planned to quit within a year. As such, it may not generalize to people who smoke cigarettes infrequently and are less certain about their quit plans. Our pharmacotherapy treatment utilization variable included Wellbutrin, Zyban, and Bupropion, which are medications used for the treatment of smoking as well as treatment of depression. This variable also included Chantix, which is exclusively used for smoking cessation. Given that depression and smoking are correlated, it may be difficult to tease apart who is taking the medication to treat depression vs. smoking cessation. However, this issue is partly addressed by our sample being limited to people who indicated a plan to quit smoking/tobacco products within a year. Lastly, we did not examine sex differences in relation to the outcome variables. These analyses may have yielded notable differences given that prior research has noted that men and women have disparate quit rates depending on what type of smoking cessation treatment is utilized (Smith, Bessette, et al., 2016; Smith, Weinberger, et al., 2016).

6. Conclusion

In our study, we longitudinally examined the relationship between SCA use initiation, NRT/prescription medication utilization, and quit attempts using a nationally representative sample of individuals who regularly smoked and planned to quit smoking within a year. Our findings suggest that SCA use initiation is associated with prescription medication utilization as well as quit attempts. Future studies should examine which types of SCAs drive this relationship and which sociodemographic factors relate to their use, and if they relate to quitting smoking. Qualitative research is also needed to better understand the relationship between SCA use initiation and prescription medication utilization.

Acknowledgements

The authors would like to acknowledge the staff, investigators, and participants from the PATH Study. This research would not be possible without their contributions. This work was supported by the National Institute of Health's Initiative for Maximizing Student Development Program (T32, 5R25GM095459-10) to Dr. Margarita L. Dubocovich; Centers for Disease Control and Prevention (R01, CE003144) to Drs. Linda S. Kahn and Gregory G. Homish; the National Institute on Drug Abuse (R01-DA034072) to Dr. Gregory G. Homish; and the National Center for Advancing Translational Sciences (UL1TR001412) to Dr. Timothy Murphy.

Data availability

Data will be made available on request.

Abbreviations:

SCA	Smoking Cessation App
NRT	Nicotine Replacement Therapy

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Table 1
PATH Study population characteristics: W2-W5 (2014/2015–2018/2019).

	W2 (n = 3,378)% (n)	W3 (n = 3,424)% (n)	W4 (n = 3,212)% (n)	W5 (n = 2,888)% (n)
SCA Use Initiation				
Yes	4 % (123)	4 % (134)	4 % (133)	5 % (158)
No	96 % (3255)	96 % (3290)	96 % (3079)	95 % (2730)
Sex				
Male	46 % (1556)	48 % (1633)	46 % (1477)	45 % (1297)
Female	54 % (1822)	52 % (1789)	54 % (1734)	55 % (1590)
Age				
18 to 24 years	17 % (558)	14 % (417)	11 % (352)	6 % (181)
25 to 34 years	24 % (807)	24 % (695)	25 % (798)	25 % (724)
35 to 44 years	20 % (681)	20 % (594)	19 % (620)	21 % (586)
45 to 54 years	20 % (676)	19 % (575)	19 % (619)	18 % (520)
55 to 64 years	14 % (492)	16 % (470)	26 % (592)	21 % (589)
65 years or older	5 % (164)	7 % (195)	7 % (241)	9 % (263)
Race				
Non-Hispanic White	63 % (2093)	61 % (1780)	62 % (1956)	60 % (1682)
Non-Hispanic Black	18 % (588)	19 % (556)	19 % (603)	21 % (581)
Hispanic	10 % (341)	10 % (287)	10 % (321)	10 % (284)
Other	9 % (302)	10 % (273)	9 % (286)	9 % (270)
Income				
Less than \$10,000	22 % (724)	24 % (672)	20 % (632)	19 % (524)
\$10,000 to \$24,999	27 % (867)	27 % (762)	27 % (845)	27 % (739)
\$25,000 to \$49,999	25 % (788)	25 % (695)	26 % (788)	25 % (691)
\$50,000 to \$99,999	20 % (632)	18 % (515)	20 % (635)	21 % (580)
\$100,000 or more	6 % (204)	6 % (181)	7 % (214)	8 % (228)
Nicotine Dependence				
Low	37 % (1233)	37 % (1067)	38 % (1220)	39 % (1091)
High	63 % (2092)	63 % (1828)	62 % (1963)	61 % (1738)
Internalizing Disorders				
None/Low Symptoms	48 % (1618)	52 % (1503)	50 % (1596)	51 % (1452)
Moderate Symptoms	26 % (865)	23 % (673)	24 % (775)	22 % (625)
High Symptoms	26 % (856)	25 % (726)	26 % (834)	26 % (734)
NRT Utilization				
Yes	14 % (464)	14 % (314)	13 % (310)	13 % (334)
No	86 % (2912)	86 % (2011)	87 % (2053)	87 % (2297)
Prescription Medication Utilization				
Yes	7 % (112)	7 % (88)	6 % (113)	8 % (107)
No	93 % (2910)	93 % (2535)	94 % (2767)	92 % (2440)
Past Year Quit Attempt				
Yes	32 % (1086)	47 % (1246)	46 % (1198)	44 % (1191)

	W2 (n = 3,378)% (n)	W3 (n = 3,424)% (n)	W4 (n = 3,212)% (n)	W5 (n = 2,888)% (n)
No	68 % (2284)	53 % (1380)	54 % (1419)	56 % (1498)

The data reported in the table are based on weighted data.

Table 2
GEE Models of Past 12 Month NRT Utilization and SCA Use Initiation.

	Past 12 Month NRT Utilization OR (95 % CI) (<i>n</i> = 7,319) (Model 1)	Past 12 Month NRT Utilization AOR (95 % CI) (<i>n</i> = 6,788) (Model 2)	Past 12 Month NRT Utilization AOR (95 % CI) (<i>n</i> = 6,741) (Model 3)
SCA Use Initiation	1.39 (0.92, 2.09)	1.45 (0.96, 2.19)	1.42 (0.95, 2.15)
Sex			
Male	N/A	Referent	Referent
Female		1.22 (0.99, 1.51)	1.18 (0.96, 1.45)
Age			
18 to 24 years old	N/A	Referent	Referent
25 to 34 years old		1.38 (0.91, 2.10)	1.42 (0.94, 2.17)
35 to 44 years old		2.00 ** (1.32, 3.02)	2.10 *** (1.40, 3.17)
45 to 54 years old		2.16 *** (1.47, 3.19)	2.30 *** (1.57, 3.37)
55 to 64 years old		2.98 *** (2.01, 4.41)	3.23 *** (2.18, 4.78)
65 years or older		3.27 *** (2.12, 5.04)	3.63 *** (2.36, 5.60)
Race			
Non-Hispanic White	N/A	Referent	Referent
Non-Hispanic Black		0.85 (0.66, 1.10)	0.89 (0.69, 1.14)
Hispanic		0.54 ** (0.37, 0.81)	0.54 ** (0.36, 0.79)
Other		1.08 (0.80, 1.44)	1.07 (0.80, 1.44)
Income			
Less than \$10,000	N/A	Referent	Referent
\$10,000 to \$24,999		0.87 (0.67, 1.13)	0.88 (0.68, 1.16)
\$25,000 to \$49,999		0.89 (0.67, 1.17)	0.91 (0.69, 1.21)
\$50,000 to \$99,999		0.98 (0.74, 1.29)	1.03 (0.78, 1.36)
\$100,000 or more		0.88 (0.59, 1.32)	0.97 (0.65, 1.46)
Nicotine Dependence			
Low Nicotine Dependence	N/A	Referent	Referent
High Nicotine Dependence		2.47 *** (1.96, 3.11)	2.37 *** (1.90, 2.97)
Internalizing Disorders			
None/low Symptoms	N/A	N/A	Referent
Moderate Symptoms			1.21 (0.97, 1.49)
High Symptoms			1.45 *** (1.19, 1.76)

* $p < 0.05$;

** $p < 0.01$;

*** $p < 0.001$.

AOR > 1.00 = the case group has higher odds of the outcome than the referent group, controlling for the other covariates in the model.

AOR < 1.00 = the case group has lower odds of the outcome than the referent group, controlling for the other covariates in the model.

The varying population sizes for each of the regression models are attributable to the following: missing data due to data removal per respondent request, “don’t know” responses, “refused” responses and individuals who did not receive the questions due to branching logic restrictions.

^aDue to the longitudinal design of the study, this refers to number of observations as opposed to number of participants.

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Table 3
GEE models prescription medication and SCA use initiation.

	Prescription Medication Utilization OR (95 % CI) (<i>n</i> = 11,072) (Model 1)	Prescription Medication Utilization AOR (95 % CI) (<i>n</i> = 10,510) (Model 2)	Prescription Medication Utilization AOR (95 % CI) (<i>n</i> = 10,422) (Model 3)
SCA Use Initiation	2.09 *** (1.43, 3.05)	1.62 * (1.04, 2.54)	2.43 *** (1.63, 3.64)
Sex			
Male	N/A	Referent	Referent
Female		1.08 (0.85, 1.35)	1.06 (0.83, 1.34)
Age			
18 to 24 years old	N/A	Referent	Referent
25 to 34 years old		1.49 (0.64, 3.47)	1.49 (0.64, 3.48)
35 to 44 years old		2.90 * (1.26, 6.64)	2.87 * (1.25, 6.59)
45 to 54 years old		4.31 *** (1.88, 9.91)	4.49 *** (1.94, 10.38)
55 to 64 years old		3.85 ** (1.59, 9.31)	4.05 ** (1.65, 9.93)
65 years old or older		6.40 *** (2.69, 15.23)	6.93 *** (2.86, 16.76)
Race			
Non-Hispanic White	N/A	Referent	Referent
Non-Hispanic Black		0.73 (0.49, 1.09)	0.76 (0.51, 1.14)
Hispanic		0.46 * (0.24, 0.88) ^b	0.47 * (0.25, 0.91) ^b
Other			
Income			
Less than \$10,000	N/A	Referent	Referent
\$10,000 to \$24,999		0.95 (0.67, 1.34)	0.97 (0.68, 1.39)
\$25,000 to \$49,999		0.90 (0.60, 1.34)	0.94 (0.62, 1.43)
\$50,000 to \$99,999		0.91 (0.59, 1.40)	0.97 (0.63, 1.50)
\$100,000 or more		1.44 (0.91, 2.27)	1.56 (0.98, 2.47)
Nicotine Dependence			
Low Nicotine Dependence	N/A	Referent	Referent
High Nicotine Dependence		1.51 ** (1.12, 2.05)	1.48 * (1.08, 2.02)
Internalizing Disorders			
None/low Symptoms	N/A	N/A	Referent
Moderate Symptoms			1.37 * (1.04, 1.81)
High Symptoms			1.21 (0.91, 1.62)

*
 $p < 0.05$;

**
 $p < 0.01$;

 $p < 0.001$.

AOR > 1.00 = the case group has higher odds of the outcome than the referent group, controlling for the other covariates in the model.

AOR < 1.00 = the case group has lower odds of the outcome than the referent group, controlling for the other covariates in the model.

The varying population sizes for each of the regression models are attributable to the following: missing data due to data removal per respondent request, “don’t know” responses, “refused” responses and individuals who did not receive the questions due to branching logic restrictions.

^aDue to the longitudinal design of the study, this refers to number of observations as opposed to number of participants.

^bEstimate could not be computed due to low cell count.

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Table 4
GEE Models of Past 12 Month Quit Attempts and SCA Use Initiation.

	Past 12 Month Quit Attempts OR (95 % CI) (<i>n</i> = 7,932) (Model 1)	Past 12 Month Quit Attempts AOR (95 % CI) (<i>n</i> = 7,394) (Model 2)	Past 12 Month Quit Attempts AOR (95 % CI) (<i>n</i> = 7,338) (Model 3)
SCA Use Initiation	1.30 * (1.05, 1.59)	1.37 * (1.07, 1.73)	1.35 * (1.06, 1.71)
Sex			
Male	N/A	Referent	Referent
Female		0.98 (0.87, 1.10)	0.97 (0.86, 1.09)
Age			
18 to 24 years old	N/A	Referent	Referent
25 to 34 years old		0.83 (0.66, 1.04)	0.84 (0.67, 1.06)
35 to 44 years old		0.84 * (0.63, 0.98)	0.81 (0.65, 1.00)
45 to 54 years old		0.77 * (0.61, 0.97)	0.79 * (0.62, 0.99)
55 or 64 years old		0.99 (0.79, 1.24)	1.02 (0.82, 1.27)
65 years or older		1.29 (0.99, 1.69)	1.33 * (1.01, 1.75)
Race			
Non-Hispanic White	N/A	Referent	Referent
Non-Hispanic Black		1.11 (0.95, 1.30)	1.13 (0.96, 1.32)
Hispanic		1.35 * (1.06, 1.72)	1.36 * (1.06, 1.73)
Other		1.16 (0.94, 1.45)	1.18 (0.94, 1.47)
Income			
Less than \$10,000	N/A	Referent	Referent
\$10,000 to \$24,999		0.84 * (0.71, 0.98)	0.85 * (0.72, 0.99)
\$25,000 to \$49,999		0.81 ** (0.69, 0.94)	0.82 ** (0.70, 0.95)
\$50,000 to \$99,999		0.83 * (0.69, 0.99)	0.84 * (0.70, 1.01)
\$100,000 or more		0.81 (0.62, 1.05)	0.82 (0.63, 1.08)
Nicotine Dependence			
Low Nicotine Dependence	N/A	Referent	Referent
High Nicotine Dependence		0.95 (0.84, 1.09)	0.94 (0.82, 1.07)
Internalizing Disorders			
None/low Symptoms	N/A	N/A	Referent
Moderate Symptoms			1.10 (0.96, 1.25)
High Symptoms			1.11 (0.96, 1.28)

* $p < 0.05$;

** $p < 0.01$;

*** $p < 0.001$.

AOR > 1.00 = the case group has higher odds of the outcome than the referent group, controlling for the other covariates in the model.

AOR < 1.00 = the case group has lower odds of the outcome than the referent group, controlling for the other covariates in the model.

The varying population sizes for each of the regression models are attributable to the following: missing data due to data removal per respondent request, “don’t know” responses, “refused” responses and individuals who did not receive the questions due to branching logic restrictions.

^aDue to the longitudinal design of the study, this refers to number of observations as opposed to number of participants.

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