Nicotine & Tobacco Research, 2017, 1–9
doi:10.1093/ntr/ntx074
Original investigation
Received March 3, 2016; Editorial Decision March 20, 2017; Accepted March 28, 2017

Original investigation

Discontinuous Patterns of Cigarette Smoking From Ages 18 to 50 in the United States: A Repeated-Measures Latent Class Analysis

Yvonne M. Terry-McElrath MSA,[1] Patrick M. O'Malley PhD,[1] Lloyd D. Johnston PhD[1]

[1]Institute for Social Research, University of Michigan, Ann Arbor, MI

Correspondence Author: Yvonne M. Terry-McElrath, MSA, Institute for Social Research, PO Box 1248, Ann Arbor, MI 48106, USA. Telephone: 734-647-9142; Fax: 734-936-0043; E-mail: yterry@umich.edu

Abstract

Introduction: Effective cigarette smoking prevention and intervention programming is enhanced by accurate understanding of developmental smoking pathways across the life span. This study investigated within-person patterns of cigarette smoking from ages 18 to 50 among a US national sample of high school graduates, focusing on identifying ages of particular importance for smoking involvement change.

Aims and Methods: Using data from approximately 15,000 individuals participating in the longitudinal Monitoring the Future study, trichotomous measures of past 30-day smoking obtained at 11 time points were modeled using repeated-measures latent class analyses. Sex differences in latent class structure and membership were examined.

Results: Twelve latent classes were identified: three characterized by consistent smoking patterns across age (no smoking; smoking < pack per day; smoking pack + per day); three showing uptake to a higher category of smoking across age; four reflecting successful quit behavior by age 50; and two defined by discontinuous shifts between smoking categories. The same latent class structure was found for both males and females, but membership probabilities differed between sexes. Although evidence of increases or decreases in smoking behavior was observed at virtually all ages through 35, 21/22 and 29/30 appeared to be particularly key for smoking category change within class.

Conclusions: This examination of latent classes of cigarette smoking among a national US longitudinal sample of high school graduates from ages 18 to 50 identified unique patterns and critical ages of susceptibility to change in smoking category within class. Such information may be of particular use in developing effective smoking prevention and intervention programming.

Implications: This study examined cigarette smoking among a national longitudinal US sample of high school graduates from ages 18 to 50 and identified distinct latent classes characterized by patterns of movement between no cigarette use, light-to-moderate smoking, and the conventional definition of heavy smoking at 11 time points via repeated-measures latent class analysis. Membership probabilities for each smoking class were estimated, and critical ages of susceptibility to change in smoking behaviors were identified.

Introduction

Tobacco use is the leading cause of preventable morbidity and mortality in the United States,[1] and cigarette sales are increasing in many low- and middle-income countries.[2] The effectiveness of smoking prevention and intervention programming may be enhanced by accurate understanding of cigarette smoking developmental pathways across the life span as well as identification of critical periods of susceptibility to change in smoking behaviors.

Smoking Trajectories

The majority of longitudinal cigarette smoking research has utilized latent growth modeling to examine smoking trajectories spanning the transition from adolescence through the 20s[3–8] or 30s.[9–19] Reviews of such research[15] show that three trajectories are consistently identified: nonsmokers (NS), occasional smokers, and heavy smokers. Most studies also identify trajectories defined by some degree of smoking frequency increase or decrease across age (varying by age of onset, rate of change in smoking frequency, and persistence of use).[20]

To the authors' knowledge, only three studies have examined cigarette smoking trajectories extending into the 40s or beyond. Brook et al.[21] modeled average daily smoking frequency among approximately 500 women at ages 40, 43, 48, and 65. Frosch et al.[22] modeled daily smoking among 232 males from ages 21 to 82. Both studies identified unique trajectories characterized by ages at which movement toward reduced use or cessation occurred. Chassin et al.[15,23] modeled the frequency of cigarettes smoked per day among approximately 8,500 individuals from ages 10 to 42, who were first surveyed as 6th–12th grade students. They defined three groups a priori (abstainers; those who initially identified as ex-smokers and never smoking thereafter; and relapsing/remitters who shifted between smoking, quitting, and smoking again). Latent class growth analysis with the remainder of cases identified six trajectories. Three trajectories persisted in smoking but differed by age of onset (ages 11, 14, and 18); three trajectories quit smoking and differed by highest smoking frequency and quit age (occasional smokers who quit by ages 21–22; regular smokers who quit by ages 27–30; heavy smokers who quit by age 37). Chassin et al.[15,23] could not use growth models for the trajectory characterized by discontinuous tobacco use because of the assumption in growth modeling that change follows a functional form over time.

One area of inquiry for longitudinal cigarette smoking research is to look for evidence of ages at which individuals appear particularly susceptible to increasing or decreasing smoking involvement. The above studies that extended into the 40s each indicated ages where change in smoking behavior occurred. However, sample sizes for Brook et al.[21] and Frosch et al.[22] are small and not representative of larger populations. Results from the study by Chassin et al.[15,23] were obtained from a large sample among the general population but limited to the US midwest. Results—indicating that the very early and late 20s, as well as mid-30s, were particularly important for change in smoking status—may be relevant for other general population samples, although regional smoking rate differences do exist.[24,25]

Sex Differences in Smoking Trajectories

The degree to which cigarette smoking varies by sex has differed across age,[26,27] historical period,[28] and geographic location.[2,24,25] Among US adults, males have been significantly more likely than females to report current smoking.[1] Less is known about the degree to which sex is differentially associated with longitudinal patterns of smoking. Males may experience higher rates of change over time in overall smoking than females.[16] Males and females are generally equally distributed across smoking trajectories in some studies.[6,15] In other research, at least some trajectories differ between males and females.[29] The literature has called for research into the degree to which males and females may differ in terms of critical ages for prevention/intervention.[16]

The Current Study

This study examines within-person patterns of past 30-day cigarette smoking from ages 18 to 50 among a large national sample of high school seniors using repeated-measures latent class analysis (RMLCA), allowing modeling of potentially discontinuous smoking patterns across age. Analyses used trichotomous smoking indicators at 11 time points to identify distinct patterns of smoking across age and to explore if some ages appeared to be of particular importance for change in smoking involvement. Three research questions (RQs) guided analyses: (1) How many unique patterns (or classes) of 30-day smoking involvement from ages 18 to 50 can be identified? (2) Are classes generally similar for males and females? (3) Are there clearly discernable ages where uptake/increased smoking or reduced use/cessation are more frequently observed?

Methods

Data, Setting, and Study Population

The study utilizes data from Monitoring the Future (MTF), a national cohort-sequential study. Detailed methodology is provided elsewhere.[27,30] Briefly, a nationally representative sample of approximately 15,000 12th graders (modal age 18) from about 130 schools in the contiguous 48 states has been surveyed annually since 1976 yielding sequential cohorts. Students complete self-administered surveys, typically during a normal class period. A sub-sample of about 2,400 12th graders is selected from each annual sample for longitudinal follow-up by mail; illicit substance users are over-sampled (analyses include weights accounting for sampling procedures). Respondents are randomly divided with half surveyed 1 year after graduation (modal age 19) and then every 2 years after that to age 29 and half surveyed 2 years after graduation (modal age 20) and then every 2 years after that to age 30 (resulting in six follow-up surveys, one at each of modal ages 19/20, 21/22, 23/24, 25/26, 27/28, and 29/30). Thereafter, respondents are surveyed four more times at 5-year intervals (modal ages 35, 40, 45, and 50). Follow-up questionnaires are mailed in the spring with a modest monetary incentive. The University of Michigan Behavioral Sciences Institutional Review Board approved the study.

The analytic sample was limited to 12th-grade cohorts from 1976 to 1982 who had the opportunity to respond to follow-up surveys through modal age 50. (These class cohorts represent modal birth cohorts of 1958–1964.) Modal age 50 data were collected during calendar years 2008–2014; see Supplemental Table 1. The average age 18 response rate for these cohorts was 81.0%. A total of 16,784 individuals from the 1976–1982 cohorts responded at age 18 and were selected for longitudinal participation. A total of 15,329 individuals (91.3%) responded to at least one of the 10 follow-up surveys. Data on sex and past 30-day cigarette use on at least one follow-up survey included in the current analyses were available for 15,247 responding individuals (90.8% of the eligible sample). Adjustments for attrition are discussed in the Analysis section.

Measures

Cigarette Smoking

At each survey, respondents were asked, "How frequently have you smoked cigarettes during the past 30 days?" 1 = not at all; 2 = less than one cigarette per day; 3 = one to five cigarettes per day; 4 = about one-half pack per day; 5 = about one pack per day; 6 = about one and one-half packs per day; 7 = two packs or more per day. To examine change between no cigarette use, light-to-moderate smoking, and the conventional definition of heavy smoking,[31,32] responses were recoded as follows: not at all; less than one pack per day (< pack/day [LPD]); pack per day or more (pack+/day [PD]).

Sex

Respondents were asked in the 12th grade survey, "What is your sex?" (response options: male, female).

Analysis

Analyses used RMLCA[33] to identify unique classes of tobacco use across ages 18–50. Latent class analysis allows use of categorical indicators, as opposed to the continuous indicators normally required for factor analysis or growth modeling.[34] Categorical indicators are especially useful for examining behaviors with non-normal distributions such as substance use. The resulting latent variable is categorical with a multinomial distribution.[34] For the current study, the repeated measure was the trichotomous smoking indicator described above; a total of 11 indicators were used, one for each of the 11 MTF data collections from ages 18–50. The resulting latent variable was comprised of classes that identified unique patterns of change in smoking: each class was defined by a specific pattern of cigarette use from ages 18 to 50. Unlike growth modeling and resulting trajectories, no functional form over time (such as quadratic growth) is assumed within class; discontinuous patterns of use over time can be modeled.[33] In addition, RMLCA enables models to account explicitly for measurement error (ie, mismatch between observed reports and class assignment) and missing data on indicators.[34] RMLCA has been used successfully to model longitudinal change in alcohol use among adolescents[35] and adults[33] and adult short-term daily smoking status.[36]All analyses were weighted using previously derived attrition weights (calculated as the inverse of the probability of responding at age 50 based on covariates measured at age 18, including sex, race/ethnicity, college plans, high school grades, number of parents in the home, religiosity, parental education, alcohol use, cigarette use, marijuana use, region of country, cohort, sampling weight correcting for over-sampling of age 18 substance users). RMLCA models were fitted in SAS 9.4 using PROC LCA.[37,38] Parameters were estimated by maximum likelihood using the EM algorithm. Because all analyses were weighted, robust standard errors based on Taylor linearization were obtained. Solution stability was based on the proportion of times the maximum-likelihood solution was selected out of 1000 random sets of starting values. Comparisons of overall participation across age within each category of smoking by sex were modeled using Joinpoint 4.2.0.2.[39,40] To ascertain if the same latent class structure was observed for males and females, multiple-group RMLCA models by sex were fitted in PROC LCA using the GROUPS statement (both with and without imposing measurement invariance across males and females).

Results

Sample Descriptives

The sample was 48.0% female. Probabilities of reporting each category of past 30-day smoking by age are presented in Figure 1 (total sample and by sex). The total sample probability of reporting no past 30-day cigarette smoking rose from a low of .63 to .64 (at ages 18 to 21/22) to .83 at age 50. In contrast, the probability of smoking LPD dropped from .27 at age 18 to .09 at age 50. The probability of smoking PD rose from .09 at age 18 to .16 from ages 21/22 to 27/28 and then decreased to .08 by age 50.

RQ 1: Latent Classes of Past 30-Day Cigarette Smoking

Trichotomous smoking indicators (none, LPD, PD) were used simultaneously in RMLCA models at each of the following ages: 18, 19/20, 21/22, 23/24, 25/26, 27/28, 29/30, 35, 40, 45, and 50. Model selection (ie, the number of latent classes specified) was determined by model fit, parsimony, and stability.[34,41] Supplemental Table 2 reports obtained fit and selection criteria. Simulations have shown that the Bayesian information criterion (BIC) and sample size-adjusted BIC (a-BIC) perform particularly well at selecting the "correct" latent class model.[42] Improvement in both BIC and consistent Akaike information criterion (CAIC) values continued only through the 12-class model; thus, the 12-class model was selected as optimal.

Latent class membership and item-response probabilities for the 12 latent classes are reported in Tables 1–2. Item-response probabilities (reflecting the probabilities of each category of smoking within latent classes) sum to 1 horizontally within age and latent class. For example, among consistent NS, probabilities at age 18 were .94 for not smoking, .06 for smoking LPD, and .00 for smoking PD (Table 1). Because item-response indicators were trichotomous, a value of .33 at any cigarette smoking category reflects random response probability. As noted above, the total sample probabilities for smoking LPD and PD peaked at .27 and .16, respectively. Given these relatively low total sample probabilties, item-response probability values of .40 or higher within a class were considered to indicate high probabilites of the specified smoking category. Three classes were characterized by smoking consistency across age (Table 1):

1. Consistent NS (class membership probability = .52, indicating that an estimated 52% of the sample were members of this class), who showed high probabilities (.94–1.00) of no past 30-day smoking at all ages;
2. Consistent LPD smokers (p =.05); and
3. Consistent PD smokers (p = .07).

Three classes were characterized by uptake to a higher smoking category across age (Table 1):

4. Uptake from no smoking to smoking < pack/day (U NS-LPD; p = .03);
5. Uptake from no smoking to smoking pack+/day (U NS-PD; p = .03); and
6. Uptake from smoking < pack/day to smoking pack+/day (U LPD-PD; p = .03).

Four classes were characterized by quitting (defined as moving from either LPD or PD smoking to high probabilities of no smoking by age 50) (Table 2):

7. Quitting < pack/day smoking early (by age 23) (Q-Early LPD; p = .08);
8. Quitting < pack/day smoking later (by age 35) (Q-Late LPD; p = .05);
9. Quitting pack+/day smoking by the mid-20s (by age 25) (Q-Mid PD; p = .03); and
10. Quitting pack+/day smoking later (by age 40) (Q-Late PD; p = .04).

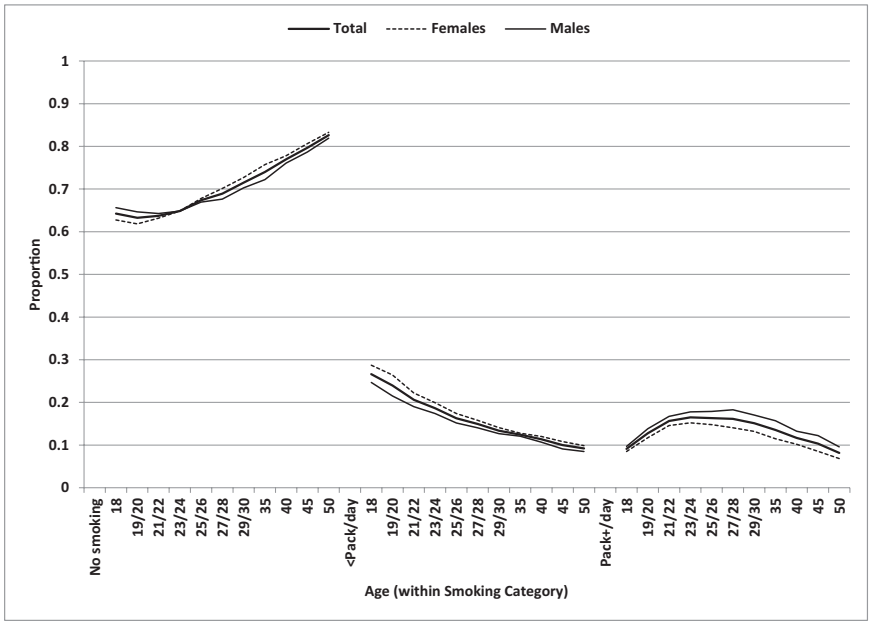

Figure 1. Proportion of respondents reporting mutually exclusive categories of past 30-day smoking by age (total and by sex). Total n = 15,247; females = 7,881; males = 7,366. Trends on the left of the figure refer to the proportions of respondents reporting no smoking from ages 18 to 50. Trends in the middle of the figure refer to the proportions of respondents reporting smoking < pack/day from ages 18 to 50. Trends on the right of the figure refer to the proportions of respondents reporting smoking pack+/day from ages 18 to 50. The heavy solid line represents the total sample. The lighter solid line represents trends for males only, whereas the dotted line represents trends for females only.

Finally, two classes were characterized by nonlinear overlapping shifts across age (Table 2):

11. Shifting from no smoking to smoking < pack/day and then back to no smoking (NS-LPD-NS; p = .04); and
12. Shifting from initially smoking < pack/day to smoking pack+/day and then returning to < pack/day (LPD-PD-LPD; p = .04).

Thus, approximately half of respondents were members of the class (1) with very low probabilities of past 30-day smoking at any age between 18 and 50. Of the remaining respondents, 20% were members of classes (7–10) that evidenced successful quit behavior by age 50; 12% were members of classes (2, 3) marked by consistent smoking across age (either LPD or PD). Nine percent (4–6) were classified as experiencing uptake to a higher category of smoking, whereas 8% (11, 12) were classified as shifting between smoking categories.

RQ 2: Differences for Males and Females

Sex-specific probabilities of reporting each category of past 30-day smoking are presented in Figure 1. Within each smoking category, both sexes showed parallel trends for overall prevalence across mean age (statistical comparison results available on request from the authors). Using the 12-class solution, multiple-group RMLCA models by sex were run with and without imposing measurement invariance on item-response probabilities (with the null hypothesis being that the more restrictive model fit the data sufficiently well). In models that contain a large number of item-response parameters (such as those in the current analyses), the distribution of the difference in likelihood-ratio difference test (G^2_Δ) may not be approximated well by chi-square if there are many degrees of freedom.[34] Thus, both G^2_Δ and AIC/BIC fit statistics were examined.[34] The likelihood-ratio test (G^2_Δ = 481.02 with 264 degrees of freedom) indicated significant (p < .001) differences for at least one item-response probability value across males and females. However, comparison of AIC and BIC values showed that the restricted model was preferred (AIC values = $14099.80_{\text{unrestricted}}$ vs. $14052.82_{\text{restricted}}$; BIC values = $18297.48_{\text{unrestricted}}$ vs. $16235.61_{\text{restricted}}$). Based on improvements in AIC/BIC values, as well as strong stability (46.9%) and entropy (0.81) in the restricted model, item-response probabilities were held invariant across males and females.

Table 3 reports sex-specific estimated class membership probabilities. An estimated 64% of males and 62% of females were members of one of the three consistent smoking classes. Estimated membership for consistent NS and LPD smoker classes were equal for males and females, but estimated membership in the consistent PD class was significantly higher for males than females. Regarding smoking uptake classes, 10% of males and 8% of females were estimated to be members of an uptake class, with no significant sex differences in uptake class membership. For the four quit classes combined, total membership was estimated at 18% for males and 22% for females. Estimated membership in the classes characterized by quitting LPD smoking was significantly higher for females than males. Membership was higher for females than males for both the class quitting LPD smoking early (by age 23) and for the class quitting LPD smoking later (by age 35). Estimated membership in classes quitting PD smoking was not significantly different between males and females. Finally, 8% of both males and females were estimated to be members of a shift class, with no significant sex differences in class membership observed.

RQ 3: Ages of Change in Smoking

Only three of the 12 classes reflected a consistent category of smoking across age. Membership in the remaining classes was differentiated by specific patterns of change between smoking categories across age. Usually, such change was evidenced by at least one age where

Table 1. Past 30-Day Cigarette Smoking From Ages 18 to 50: Parameter Estimates for Consistent and Uptake Classes

Latent class and membership probability	1. Consistent nonsmokers (NS) .52			2. Consistent < pack/day (LPD) .05			3. Consistent pack+/day (PD) .07		
	Item-response probabilities								
	NS	LPD	PD	NS	LPD	PD	NS	LPD	PD
Modal age									
18	**.94**	.06	.00	.22	**.73**	.06	.05	.29	**.66**
19/20	**.98**	.02	.00	.12	**.80**	.07	.00	.05	**.95**
21/22	**.98**	.02	.00	.10	**.82**	.08	.02	.04	**.94**
23/24	**.99**	.01	.00	.11	**.80**	.09	.02	.05	**.92**
25/26	**.99**	.01	.00	.10	**.86**	.05	.02	.02	**.95**
27/28	**.99**	.01	.00	.06	**.91**	.03	.01	.03	**.96**
29/30	**1.00**	.00	.00	.11	**.86**	.03	.04	.03	**.93**
35	**.99**	.01	.00	.10	**.79**	.11	.04	.06	**.89**
40	**1.00**	.00	.00	.06	**.83**	.11	.05	.04	**.91**
45	**1.00**	.00	.00	.09	**.81**	.10	.09	.10	**.82**
50	**1.00**	.00	.00	.20	**.71**	.09	.19	.15	**.66**
	4. Uptake: no smoking → < pack/day (U NS-LPD) .03			5. Uptake: no smoking → pack+/day (U NS-PD) .03			6. Uptake: < pack/day → pack+/day (U LPD-PD) .03		
18	**.65**	.32	.03	**.62**	.34	.04	.32	**.61**	.06
19/20	**.66**	.30	.03	**.64**	.35	.02	.18	**.79**	.03
21/22	**.72**	.24	.03	***.47***	***.49***	.04	.08	***.40***	***.53***
23/24	**.76**	.21	.03	.28	**.58**	.13	.00	.22	**.78**
25/26	**.83**	.16	.01	.20	**.54**	.25	.00	.05	**.95**
27/28	**.87**	.13	.00	.10	***.44***	***.47***	.02	.09	**.89**
29/30	**.78**	.22	.00	.08	***.42***	***.50***	.06	.07	**.87**
35	***.44***	***.53***	.04	.07	.23	**.70**	.05	.03	**.92**
40	.22	**.68**	.11	.10	.28	**.62**	.05	.05	**.90**
45	.25	**.63**	.11	.15	.26	**.59**	.00	.05	**.95**
50	.30	**.59**	.11	.26	.30	**.44**	.19	.11	**.70**

Unweighted n = 15,247. Bold font indicates item-response probabilities of .40 or higher. Underlined probabilities within class indicate ages where members had probabilities of .40 or higher for more than one smoking category.

probabilities were at or above .40 in more than one smoking category (hereafter referred to as shifts). For example, Table 2 shows that the Q-Early LPD class shift from high probabilities of smoking LPD to NS occurred at age 21/22, when probabilities of both NS and smoking LPD were high (.51 and .46, respectively). Two of the quit classes (Q-Mid PD and Q-Late PD) did not have shifts meeting the requirement of probabilities at or above .40 in two smoking categories; for these classes only, shifts were defined as ages having probabilities at or above .35 in two smoking categories.

Shifts were not observed at ages 25/26, 40, 45, or 50 (see Supplemental Table 3). Shifts to a higher category of smoking were observed at all remaining ages (18, 19/20, 21/22, 23/24, 27/28, 29/30, and 35). Shifts to a lower category of smoking were observed at ages 21/22, 23/24, 29/30, and 35. Shifts appeared most frequently at ages 21/22 and 29/30. At 21/22, shift to a higher smoking category occurred in three classes (NS-LPD-NS; U NS-PD; and U LPD-PD) and shift to a lower smoking category occurred in one class (Q-Early LPD). At 29/30, shift to a lower smoking category occurred in three classes (Q-Late LPD; NS-LPD-NS; and LPD-PD-LPD) and shift to a higher smoking category occurred in one class (U NS-PD). Given that grouping analyses (previously discussed) indicated item-response probabilities could be held invariant across males and females, observed shifts did not vary by sex.

Discussion

This study explored within-person latent classes of past 30-day cigarette smoking from ages 18 to 50 in a large national sample and identified 12 latent classes: three characterized by consistent patterns of smoking across age (no smoking, LPD, and PD); three showing uptake to a higher category of smoking across age; four reflecting successful quit behavior by age 50; and two defined by discontinuous shifts between smoking categories. Although these classes were found for both males and females, membership probabilities were not equal between sexes. There was little evidence for change in smoking behavior after age 35. Although some degree of increase or decrease in smoking behavior was observed at virtually all ages up through 35, 21/22 and 29/30 appeared to be particularly key for change in smoking involvement.

During the years of data collection for the current study (1976–2014), the estimated percentage of US adults who were current smokers dropped from 37%[43] to 17%.[1] Even at 17%, approximately 40 million US adults reported current smoking.[1] Any degree of cigarette smoking is harmful; the longer smoking behavior occurs, the greater the damage.[44] Conversely, the sooner cessation is achieved, the greater the likelihood of improving health outcomes.[44] Smoking reduction (decreases in the number of cigarettes smoked per day) is not associated directly with improved health outcomes but does

Table 2. Past 30-Day Cigarette Smoking From Ages 18 to 50: Parameter Estimates for Quit and Shift Classes

Latent class and membership probability	7. Quit early < pack/day (Q-Early LPD) .08			8. Quit later < pack/day (Q-Late LPD) .05			9. Quit by mid-20s pack+/day (Q-Mid PD) .03			10. Quit later pack+/day (Q-Late PD) .04		
	Item-response probabilities											
	NS	LPD	PD	NS	LPD	PD	NS	LPD	PD	NS	LPD	PD
Modal age												
18	**.45**	**.54**	.02	.21	**.74**	.05	.20	*.37*	***.44***	.27	**.41**	.32
19/20	.31	**.67**	.02	.02	**.92**	.06	.10	.22	**.68**	.14	*.35*	***.50***
21/22	**.51**	**.46**	.03	.11	**.82**	.07	.24	.18	**.58**	.09	.18	**.73**
23/24	**.69**	.30	.01	.13	**.85**	.01	*.39*	.15	***.47***	.09	.14	**.77**
25/26	**.88**	.10	.01	.17	**.81**	.03	**.66**	.13	.21	.09	.14	**.77**
27/28	**.91**	.09	.00	.29	**.67**	.05	**.87**	.09	.03	.06	.18	**.77**
29/30	**.93**	.06	.01	**.44**	**.52**	.04	**.92**	.05	.04	.20	.16	**.65**
35	**.97**	.03	.00	**.63**	.36	.00	**.86**	.10	.05	**.52**	.13	*.35*
40	**.97**	.03	.00	**.78**	.21	.01	**.88**	.05	.07	**.79**	.09	.12
45	**.98**	.02	.00	**.91**	.09	.00	**.87**	.06	.07	**.98**	.02	.01
50	**.99**	.01	.00	**.93**	.06	.01	**.89**	.06	.05	**.95**	.01	.03

	11. Shift: no smoking → < pack/day→ no smoking (NS-LPD-NS) .04			12. Shift: < pack/day → pack+/day → < pack/day (LPD-PD-LPD) .04		
18	**.77**	.20	.03	.08	**.67**	.25
19/20	**.96**	.04	.00	.02	**.51**	**.47**
21/22	**.58**	**.41**	.01	.01	.38	**.61**
23/24	**.41**	**.54**	.05	.01	.30	**.69**
25/26	.32	**.62**	.06	.06	.35	**.59**
27/28	.38	**.55**	.07	.08	.33	**.59**
29/30	**.49**	**.47**	.04	.08	**.41**	**.51**
35	**.62**	.36	.02	.08	**.57**	.35
40	**.82**	.16	.02	.09	**.68**	.23
45	**.90**	.10	.00	.16	**.64**	.20
50	**.94**	.06	.00	.26	**.54**	.20

Unweighted n = 15,247. NS = no smoking; LPD = < pack/day; PD = pack+/day. Bold font indicates item-response probabilities of .40 or higher. Underlined probabilities within class indicate shift ages where members had probabilities of .40 or higher for more than one smoking category. For Q-Mid PD and Q-Late PD, shift ages (underlined in italics) were identified as those where probabilities of .35 or higher were found for more than one smoking category.

increase the likelihood of eventually attempting and achieving cessation.[45] To examine consistency, reduction, and increase in smoking among US adults, the current study examined three categories of past 30-day smoking: no smoking, LPD, and PD. Similar to findings based on other populations,[4,15,20,23] approximately half of the current sample of the classes of 1976–1982 were estimated to belong to the consistent NS class, leaving half to engage in some degree of smoking behavior at some point by age 50. Given that only 12% were members of classes marked by consistent smoking across age, most individuals who engaged in smoking did so at varying degrees of involvement across ages 18 to 50. At age 50 (in calendar years 2008–2014), 76% of the sample were estimated to be members of classes that reported high probabilities of no smoking; 12% members of classes with high probabilities of smoking LPD; and 13% members of classes with high probabilities of smoking PD.

Careful attention to the overall total probabilities of smoking categories and estimated class membership probabilities highlights the latent (vs. observed) nature of RMLCA models, both in modeling class assignment error as well as varying probabilities of different behaviors across classes. For example (as stated above), the proportion of the sample estimated to be members of classes characterized by high probabilities of smoking LPD at age 50 was 0.12, whereas the total sample probability of smoking LPD at age 50 was .09 (see Figure 1). Tables 1 and 2 show that among classes characterized by high probabilities of not smoking or smoking PD, there were still low probabilities of smoking LPD. For example, among the class characterized by consistent PD smoking, the probability of smoking LPD at age 50 was .15, and not zero.

Almost one in 10 respondents were estimated to be members of classes characterized by uptake to a higher category of past 30-day smoking after age 18; 6% of respondents were estimated to be members of classes characterized by uptake from not smoking to smoking. Because only eight cohorts were examined in the current analyses (high school seniors from 1976 to 1982), we did not fit models that examined the degree to which membership in identified latent smoking classes changed over historical time. National data from Canada in 2005 estimated that up to 20% of those who ever smoked first did so after age 18,[46] and the likelihood of first smoking after age 20 has increased significantly since the late 1970s.[47] Future research may find that membership in classes characterized by uptake to a higher category of smoking across age is higher than that found in the current study.

More than two-thirds of adult US cigarette smokers desire to quit;[48] quitting smoking at any age is beneficial to health.[44] Twenty percent of respondents in the current study were members of classes that evidenced

Table 3. Estimated Latent Class Membership Probabilities by Sex for 12-Class Model of Past 30-Day Cigarette Smoking From Ages 18 to 50

	Males		Females	
Latent class	Prob.[a]	(95% CI)	Prob.	(95% CI)
Consistent classes				
1. Nonsmokers	.52	(.500, .536)	.52	(.496, .535)
2. < Pack/day	.05	(.035, .060)	.05	(.041, .065)
3. Pack+/day	**.08**	(.066, .085)	**.05**	(.046, .061)
Sub-total	.64		.62	
Uptake classes				
4. No smoking → < pack/day	.03	(.021, .038)	.02	(.016, .032)
5. No smoking → pack+/day	.04	(.029, .050)	.03	(.017, .036)
6. < Pack/day → pack+/day	.04	(.027, .044)	.03	(.019, .033)
Sub-total:	.10		.08	
Quit classes				
7. Quit < pack/day early (by age 23)	**.06**	(.044, .076)	**.10**	(.084, .117)
8. Quit < pack/day later (by age 35)	**.04**	(.028, .052)	**.06**	(.052, .077)
9. Quit pack+/day mid-20s (by age 25)	.03	(.022, .037)	.02	(.015, .029)
10. Quit pack+/day later (by age 40)	**.05**	(.040, .058)	.04	(.026, .045)
Sub-total:	.18		.22	
Shift classes				
11. No smoking → < pack/day → no smoking	.05	(.032, .061)	.03	(.021, .043)
12. < Pack/day → pack+/day → < pack/day	**.03**	(.020, .041)	.05	(.037, .055)
Sub-total:	.08		.08	

Unweighted n = 15,247 (overall); male = 7,366; female = 7,881. Bold font indicates probabilities with nonoverlapping confidence intervals.
[a]Prob. = Estimated class membership probabilities.

successful quit behavior by age 50. Membership in classes quitting LPD smoking was almost twice as high as membership in classes quitting PD smoking: 13% versus 7%. If shift class NS-LPD-NS membership is also considered, estimated overall membership in classes quitting LPD smoking rises to 17%. The markedly lower membership in classes quitting PD smoking likely reflects higher daily nicotine intake among PD smokers and its role in smoking addiction.[49,50]

The same latent classes of smoking were identified for males and females in the current study. Both sexes were equally likely to be consistent NS or consistent LPD smokers. Males were significantly more likely to be members of the class defined by consistently smoking PD, whereas females were more likely to be members of classes quitting LPD smoking. These findings underscore research indicating that although both genders have similar smoking trajectories,[6,15] adult males are more likely than females to report current smoking.[1] Prevention and cessation efforts should target adults of both sexes equally (especially in regard to the risk of uptake to higher smoking involvement) but recognize that overall smoking frequency is likely to be higher for males than females.

As noted previously, there may be specific ages where individuals are particularly susceptible to changes in smoking behavior. Chassin et al.[15,23] found that the very early and late 20s, as well as mid-30s, appeared to be ages of particular change in smoking status. The current study found that within classes, shifts between smoking categories appeared at almost all ages up through 35 but were concentrated at 21/22 and 29/30. The ages of 17–22 and 28–33 have been identified as key transitional periods in adult development;[51] such transitional periods involve reappraising the existing structure of life and moving toward commitment to choices that will form the basis for structure in the following developmental periods.[51] The early and late 20s may be especially important periods for tobacco use prevention and intervention. Industry documents show tobacco companies have long been aware that young adults have the highest relative quit rate, particularly those aged 18 to 21.[52] Yet, within-class shifts between smoking categories were observed at almost all ages up to 35 in the current study, pointing to the importance of not focusing prevention/intervention efforts solely on the early and late 20s. This is underscored by the finding that an estimated 6% of respondents were members of classes characterized by a shift to increased smoking as late as 29/30 and 35. Smoking-related beliefs and behaviors vary across age;[53,54] such variance should be considered when developing smoking prevention and intervention efforts.

Limitations

The current study is subject to limitations. Findings may not generalize to individuals who drop out of school prior to their senior year (approximately 15% of these cohorts[55]); lower educational attainment is associated with higher smoking initiation risk.[56–60] The trajectories modeled are based on repeated measures of past 30-day cigarette smoking. Thus, "quitting" may not reflect complete cessation of smoking involvement; "no smoking" may not reflect total abstinence. All data are based on self-reports, which have been found to be reasonably reliable and valid under appropriate conditions which the MTF study has striven to provide.[26,61–63] Finally, data collection from age 18 to 29/30 occurred every 2 years; data collection from then on occurred at 5-year intervals. Possible fluctuation in smoking patterns occurring within the 5-year intervals after age 30 would not be detected. These limitations notwithstanding, the current study contributes significantly to available knowledge on cigarette smoking trajectories among the general adult population of high school graduates.

Conclusion

This examination of cigarette smoking among a national US longitudinal sample not only identified characteristics and membership

probabilities of unique developmental smoking classes (each defined by a specific pattern of cigarette use from ages 18 to 50) but also indicated critical periods of susceptibility to change in smoking behaviors. Such information may be of particular use in developing more effective cigarette smoking prevention and intervention programming.

Supplementary Material

Supplementary data are available at *Nicotine & Tobacco Research* online.

Funding

Monitoring the Future is supported by the National Institute on Drug Abuse (DA001411 and DA016575). No other financial disclosures are reported by the authors of this article. The views expressed in this article are those of the authors and do not necessarily reflect the views of the funders.

Declaration of Interests

None declared.

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