Original Investigation

Cigarette Smoking Among College Students: Longitudinal Trajectories and Health Outcomes

Kimberly M. Caldeira, M.S.,¹ Kevin E. O'Grady, Ph.D.,² Laura M. Garnier-Dykstra, M.A.,¹ Kathryn B. Vincent, M.A.,¹ Wallace B. Pickworth, Ph.D.,³ & Amelia M. Arria, Ph.D.^{1,4}

¹ Center on Young Adult Health and Development, Department of Family Science, University of Maryland School of Public Health, College Park, MD

² Department of Psychology, University of Maryland, College Park, MD

³ Battelle Centers for Public Health Research and Evaluation, Baltimore, MD

⁴ Treatment Research Institute, Philadelphia, PA

Corresponding Author: Amelia M. Arria, Ph.D., Center on Young Adult Health and Development, Department of Family Science, University of Maryland School of Public Health, 1142 School of Public Health Building, College Park, MD 20742, USA. Telephone: 301-405-9795; Fax: 301-314-1013; E-mail: aarria@umd.edu

Received January 12, 2011; accepted June 24, 2011

Abstract

Introduction: Light and intermittent patterns of cigarette smoking are prevalent among U.S. college-aged individuals. It is unclear whether intermittent smokers maintain their use over time or are transitioning to daily use or nonuse, and whether they experience more adverse health outcomes than nonsmokers.

Methods: This study examined the trajectories of tobacco cigarette smoking, their predictors, and health outcomes among students ($N = 1,253$) assessed during their first year of college (Y_1) and annually thereafter (Y_2 , Y_3 , and Y_4).

Results: In Y_1 , 3.4% smoked daily and 4.1% exhibited signs of dependence (first cigarette within 30 min of waking). Growth curve modeling identified five distinct smoking trajectories. After stable nonsmokers (71.5%_{wt}), the low-stable smoking trajectory was the most common (13.3%_{wt}), outnumbering both low-increasing (6.5%_{wt}) and high-stable smokers (5.5%_{wt}) by 2:1 and high-decreasing smokers (3.2%_{wt}) by 4:1. The likelihood of maintaining a low level of smoking over time was inversely related to Y_1 smoking frequency. Few demographic, smoking, and alcohol use characteristics measured in Y_1 distinguished low-increasers from low-stable smokers or high-decreasers from high-stable smokers. By Y_4 , high-stable smokers rated their health significantly worse than all others except low-increasers. High-stable smokers had the most Y_4 health problems (i.e., provider visits for health problems and days of illness-related impairment), but only among nonWhites.

Conclusions: Many college students smoke, but few smoke daily or are nicotine dependent. Intermittent smoking patterns are often stable throughout college and are associated with adverse health outcomes. Prevention strategies should be designed to mitigate the possible long-term health consequences of light and intermittent smoking.

doi:10.1093/ntr/nts131

Advance Access Published on May 15, 2012

© The Author 2012. Published by Oxford University Press on behalf of the Society for Research on Nicotine and Tobacco. All rights reserved. For permissions, please e-mail: journals.permissions@oup.com

Introduction

Young adults have the highest smoking rates of any age group in the United States (Rock et al., 2007; Substance Abuse and Mental Health Services Administration, 2010); however, recent research indicates that young adult smoking may not mirror the typical daily habitual smoking of earlier generations. Light or intermittent smoking is common among young adults (Lenk, Chen, Bernat, Forster, & Rode, 2009; Wetter et al., 2004; White, Bray, Fleming, & Catalano, 2009) and typifies a pattern of smoking in social situations (Moran, Wechsler, & Rigotti, 2004; Waters, Harris, Hall, Nazir, & Waigandt, 2006).

Among current smokers, intermittent smoking is more common among minorities (relative to Whites), young adults aged 18–24 (relative to 45–64 year olds), and individuals with a college education (relative to those with less education; Trinidad et al., 2009; Wortley, Husten, Trosclair, Chrismon, & Pederson, 2003). Among young adults, intermittent smokers smoke fewer cigarettes per day than daily smokers (Hassmiller, Warner, Mendez, Levy, & Romano, 2003; Lenk et al., 2009; Levy, Biener, & Rigotti, 2009), are less likely to feel addicted (Lenk et al., 2009), and less likely to consider themselves “smokers” (Lenk et al., 2009; Waters et al., 2006). In one study of 990 young adults, 17%–21% were intermittent smokers, and although college-attending individuals were less likely to smoke heavily than their noncollege-attending counterparts, they were equally likely to be light or intermittent smokers (White et al., 2009).

A number of longitudinal studies spanning adolescence and early adulthood have identified two or more distinct smoking trajectories, yet most of these studies have relied on smoking measures that are not sensitive to the difference between intermittent and daily smoking (Chassin, Presson, Pitts, & Sherman, 2000; Juon, Ensminger, & Sydnor, 2002; White, Johnson, &

Buyske, 2000; White, Nagin, Replogle, & Stouthamer-Loeber, 2004; White, Pandina, & Chen, 2002). Three studies have investigated intermittent smoking patterns longitudinally among young adults, yet it remains unclear whether intermittent smoking is truly a distinct stable pattern of use. First, Colder et al. (2006) documented an overall decrease in smoking over the course of the first year of college but did not distinguish between groups with different smoking patterns. Second, in their study of 548 college students, Wetter et al. (2004) found that 87% of daily smokers and 50% of occasional smokers continued to smoke 4 years later, and occasional smokers were more likely to quit than to maintain their occasional pattern of use or transition to daily use. However, with only two waves of data, the study could not describe the stability of smoking patterns throughout the follow-up period. Third, following students from their final year in high school to 2-years post-high school, White et al. (2009) found that heavy smoking was much more stable than light smoking, in that 79% of heavy smokers remained heavy smokers 2 years later, but less than half of light smokers remained light smokers. The latter two studies grouped all intermittent users together, rather than differentiating between higher and lower levels of intermittent smoking, as suggested by Lenk et al. (2009). Moreover, they raised important questions about the relationship between alcohol use and changes in smoking behavior. In the White et al. (2009) study, intermittent smokers engaged in binge drinking more frequently than nonsmokers, which also increased their likelihood of transitioning to a heavier smoking pattern in the future, but in the Wetter et al. (2004) study, drinking patterns of occasional smokers were not related to subsequent smoking behavior changes.

Thus, it is unclear whether intermittent smokers are in transition to daily use or nonuse or are part of an emerging cohort of stable intermittent light smokers. Examining smoking trends is extremely important given the health consequences of smoking, even at low levels. The U.S. Surgeon General's most recent report on smoking-attributable disease concluded that even light and occasional smoking can cause physiological changes that substantially increase cardiovascular risk (United States Department of Health and Human Services, 2010). In college/graduate students, Halperin, Smith, Heiligenstein, Brown, and Fleming (2010) found that any smoking, including light or intermittent smoking, was associated with negative outcomes including depression and use of emergency and mental health services. Yet, Korhonen, Broms, Levalahti, Koskenvuo, and Kaprio (2009) found no link between consistent intermittent smoking and increased likelihood of lung cancer.

The present study aimed to: (a) describe the trajectories of cigarette smoking in a large college student sample, (b) identify correlates that distinguish between smoking trajectories, (c) examine the relationship between baseline smoking patterns and subsequent trajectory membership, and (d) evaluate the predictive validity of smoking trajectories with respect to three health outcomes (general health rating, service utilization for physical health problems, and health-related functional impairment). Analyses focused on exploring the relative stability of intermittent (i.e., nondaily) smoking patterns, the extent to which intermittent smokers transitioned to heavier or lighter use, and risk factors and outcomes associated with divergence or convergence of different smoking trajectories.

Methods

Study Design

Data were collected as a part of the College Life Study, a large ongoing prospective study investigating health risk behaviors among students attending a large mid-Atlantic university. After screening 82% of the incoming class of first-time first-year students, aged 17–19, in the summer before college entry ($n = 3,401$), we purposively oversampled students who used an illicit drug or nonmedically used a prescription drug at least once prior to college (100% probability) and randomly sampled all others (40% probability) for the longitudinal study, after stratifying by race and gender to ensure demographic diversity. The resulting cohort of 1,253 completed the 2-hr baseline (Y_1) assessment (response rate = 86.5%), consisting of a personal interview and self-administered questionnaires, sometime during their first year of college (2004–2005). All 1,253 were contacted for similar follow-up assessments annually (Y_2 , Y_3 and Y_4), regardless of continued college attendance; 81% completed all four annual assessments. Each annual assessment was administered over a 9-month interval corresponding to the academic year, with follow-up assessments occurring on or near the Y_1 anniversary. Details on sampling, recruitment, and interview procedures are available elsewhere (Arria et al., 2008; Vincent et al., 2012). Participants were paid for each assessment. The study received university Institutional Review Board approval. Informed consent and a Federal Certificate of Confidentiality were obtained. Interviewers were trained extensively in research procedures and human subjects protections.

Sample

The sample's ($N = 1,253$) average Y_1 age was 18.2, 51.4% were female and 73.1% were White. Analyses on Y_4 health outcomes were restricted to the 1,090 participants who completed the Y_4 assessment and had nonmissing data on demographic variables. Included and excluded participants differed slightly with respect to sex (53.8% vs. 36.2% female, respectively, $p < .001$), Y_1 smoking (23.1% vs. 31.3% past-month smokers, respectively, $p < .05$), and age (mean 18.2 vs. 18.3 years, respectively, $p < .001$) but were similar with respect to race and neighborhood income.

Measures

Tobacco Use

Annually (Y_1 through Y_4), participants were asked how many days they smoked in the past month and how many cigarettes they smoked per smoking day. Past-month smoking frequency at Y_1 was later recoded into nonsmokers (0 days), daily smokers (30 days), and three mutually exclusive groups of intermittent smokers: infrequent-intermittent smokers (1–3 days), moderate-intermittent smokers (4–13 days), and frequent-intermittent smokers (14–29 days). Our choice of cutpoints was influenced by Lenk et al. (2009), who divided intermittent smokers into two groups, and we added the third “infrequent” category to set apart the relatively large number of individuals whose smoking frequency approximated a pattern of less-than-weekly use. The count variable was used for the trajectory analysis, and the categorical variable was used in subsequent analyses predicting smoking trajectory group membership (see Statistical Analysis below).

Health Outcomes

In Y_4 , participants rated their overall health as either excellent, good, fair, or poor. Responses were later dichotomized as excellent/good and fair/poor. Two other interview questions asked how many times in the past year participants visited a medical health professional for physical health problems (i.e., service utilization), and the number of days their usual activities were limited due to an illness or physical condition (i.e., functional impairment).

Nicotine Dependence

Time to first cigarette of the day was used as a measure of nicotine dependence (Heatherton, Kozlowski, Frecker, Rickert, & Robinson, 1989). Responses were later dichotomized as within 30 min and after 30 min.

Alcohol Use and Dependence

Annually, participants were asked how many alcoholic drinks they typically consumed on days they drank alcohol in the past year. A show card depicted standard drink sizes. Alcohol dependence was assessed annually using standard questions (Substance Abuse and Mental Health Services Administration, 2003) corresponding to *DSM-IV* criteria (American Psychiatric Association, 1994). Individuals were coded as alcohol dependent in the past year if they endorsed three or more dependence criteria; all others were coded as nondependent.

Demographics

Sex was recorded by the interviewer. Race was self-reported and dichotomized as White and nonWhite. Age at Y_1 was self-reported. As a proxy for family income, neighborhood income was used from the students' permanent residence, based on publicly available Internal Revenue Service data on mean adjusted gross income by ZIP code (MelissaDATA, 2003).

Statistical Analysis

To statistically adjust for our purposive sampling design, sampling weights were computed within each race-sex-drug use cell as the number of individuals in the sampling frame divided by the number of sampled individuals. This statistical weighting procedure enabled us to produce prevalence estimates for trajectory group membership that would represent the original target population of all first-year students. However, all other analyses were conducted using unweighted data.

We adopted a data-driven approach to identify distinct trajectories of smoking. For the first aim, we analyzed the four annual repeated measures of past-month smoking frequency with a multivariate mixture model allowing for up to a third-degree polynomial to define rates of change over time, with assessment year as the time variable, and assuming a zero-inflated Poisson distribution for smoking frequency, using PROC TRAJ (Jones, Nagin, & Roeder, 2001) in SAS (SAS Institute Inc., 2008). Examination of the Bayesian Information Criterion (BIC) associated with solutions for one through five groups indicated a five-group structure produced the smallest absolute value BIC and was therefore selected as the best fit to the data. The six-group solution further improved the BIC somewhat, but it was rejected due to the accumulation of very small group sizes (i.e., two groups representing <5% of the sample) without meaningful gains in interpretability. Parameter estimates were evaluated for linear, quadratic, and cubic effects within each

smoking trajectory group and compared across the five groups to evaluate differences in the smoking trajectory groups in their respective slopes. Differences in trajectory intercepts were evaluated at Y_1 and Y_4 , respectively, by reparameterizing the model around different intercept locations. For the second aim, analyses sought to further characterize any Y_1 distinctions between the five smoking trajectory groups, via between-groups comparisons of demographic characteristics (race, sex, age, and neighborhood income) and Y_1 smoking and alcohol use patterns using chi-square goodness-of-fit tests and one-way ANOVAs.

Analyses for the third aim built on preceding analyses by treating the smoking trajectory groups as outcomes and examining how individuals with different early smoking patterns eventually sorted themselves out into the five smoking trajectory groups. Using the five-level a priori categorical variable on Y_1 smoking frequency (see Measures section), we compared the probabilities of smoking trajectory group membership. Finally, to shed light on possible differential health consequences that might be associated with smoking trajectory group membership, three separate regression models were used to test the ability of smoking trajectory group membership to predict the three Y_4 health outcomes. Health rating (dichotomous) was analyzed using logistic regression and provider visits and impairment (both count variables) using overdispersed negative binomial regression. Pairwise comparisons between smoking trajectory groups were evaluated using Bonferroni correction if the overall chi-square test was significant ($\alpha = .05$). Sex, race, and neighborhood income were held constant, and their first-order interactions with the smoking trajectory group variable were tested.

Results

Smoking Pattern Trajectories

The five smoking trajectories are depicted in Figure 1. The largest group (63.1% of the sample; "stable nonsmokers") had consistently low or negligible smoking frequencies with means near zero. Two groups began college with very low smoking frequencies, some maintaining their low level of smoking throughout college (16.0% of the sample; "low-stable smokers"), others smoking more frequently with time (8.3% of the sample; "low-increasing smokers"). The two remaining groups both started college with relatively high smoking levels, one maintaining that pattern throughout college (8.3% of the sample; "high-stable smokers"), the other cutting back substantially (4.3% of the sample; "high-decreasing smokers"). After statistically weighting the sample to adjust for our purposive sampling design, we estimate that 71.5%_{wt} of students in the original target population were stable nonsmokers, 13.3%_{wt} were low-stable, 6.5%_{wt} were low-increasers, 5.5%_{wt} were high-stable, and 3.2%_{wt} were high-decreasers. Subsequent analyses focus on identifying factors that help distinguish between groups that either diverged from a similar smoking pattern after Y_1 (e.g., low-increasing from low-stable) or converged toward a similar smoking pattern by Y_4 (e.g., high-decreasing and low-stable).

BIC values, parameter estimates, and probabilities of trajectory group membership are available as Supplementary Tables 1–3. In summary, significant changes in smoking frequency occurred within all but the stable nonsmokers. Mean probability of membership in each of the five groups ranged

Cigarette smoking among college students

Figure 1. Trajectories of cigarette smoking during 4 years of college ($n = 1,253$). Means and SE bars of number of smoking days in the past month depicted at each timepoint. The percentages shown in the figure are unweighted. After statistically weighting the sample to adjust for our purposive sampling design, we estimate that 71.5%_{wt} of students in the original target population were stable nonsmokers, 13.3%_{wt} were low-stable, 6.5%_{wt} were low-increasers, 5.5%_{wt} were high-stable, and 3.2%_{wt} were high-decreasers.

from .91 to .99. Pairwise comparisons of trajectory slopes indicated that the trajectory shapes were significantly different from each other, with the exception that the stable nonsmokers' trajectory shape was not significantly different from that of the low-stable or high-stable groups (results available upon request).

Comparisons of Smoking Trajectory Group Means

Between-group comparisons of smoking trajectory intercepts at Y_1 and Y_4 illustrate the divergence and convergence of certain trajectories. High-decreasers initially (Y_1) smoked somewhat less than high-stable smokers (Figure 1; 14.3 vs. 18.2, $p < .001$), but by Y_4 , they were smoking only slightly more than the low-stable group (2.6 vs. 1.7, $p < .001$). Conversely, low-increasers initially (Y_1) smoked no more frequently than the low-stable group (1.3 vs. 1.2 days, $p = .44$) and subsequently diverged, yet never approached the high-stable mean, even in Y_4 (15.5 vs. 23.8, $p < .001$). All remaining comparisons were statistically significant at $p < .003$.

Comparison of Y_1 Characteristics of Smoking Trajectory Groups

Bivariate comparisons revealed significant differences between smoking trajectory groups on both demographic and Y_1 substance use characteristics (Table 1). Both males and Whites were slightly over-represented in all four smoking trajectory groups (relative to stable nonsmokers). No differences in age or neighborhood income were observed. Stable nonsmokers also had less alcohol involvement as measured by past-year drinking, typical alcohol consumption, and alcohol dependence, although some comparisons did not achieve statistical significance. Comparing the low-stable and low-increasing groups, Y_1 smoking patterns were similar in terms of time since first

cigarette (2.7 vs. 2.9 years), past-month smoking (49.5% vs. 41.0%), number of cigarettes per day (1.5 vs. 1.5), and their alcohol involvement were also similar. The high-decreasing and high-stable groups were not significantly different, although high-stable smokers had been smoking somewhat longer (4.1 vs. 3.5 years) and more heavily (4.7 vs. 3.5 cigarettes/day) than the high-decreasing group, and their Y_1 alcohol involvement was strikingly similar. The presence of minimal smoking behavior among stable nonsmokers reflects within-group variability permitted by PROC TRAJ, which assigns trajectory group membership based on probabilities (see Supplementary Table 3).

Probability of Smoking Trajectory Group Membership by Y_1 Smoking Pattern

Table 2 depicts the proportion of students in each Y_1 smoking pattern who progressed into each of the five smoking trajectory groups. Smoking patterns were relatively stable over the 4 years of college. Following the first row of Table 2, first-year nonsmokers were unlikely to develop a significant smoking pattern by the end of college: 81.7% remained stable nonsmokers, whereas only 10.8% followed a low-stable trajectory, 6.2% followed a low-increasing trajectory, 0.5% followed a high-decreasing trajectory, and 0.7% followed a high-stable trajectory. Conversely, students who were daily smokers at Y_1 were very likely to maintain that pattern (79.1% high-stable). Regarding relative stability of intermittent smoking patterns, moderate-intermittent smokers exhibited the greatest heterogeneity, with approximately equal proportions sorting into each of the four smoking trajectories (24.2% low-stable, 21.2% low-increasing, 25.8% high-decreasing, and 28.8% high-stable). On the other hand, infrequent-intermittent smokers usually maintained low levels of smoking (59.9% low-stable), and

Table 1. Characteristics of First-Year College Students by Smoking Trajectory Group (N = 1,253)

	Total sample (N = 1,253)	Smoking trajectory groups					p value
		Stable nonsmoking (n = 791)	Low-stable (n = 204)	Low-increasing (n = 100)	High-decreasing (n = 55)	High-stable (n = 103)	
% Male	48.5	44.6 ^a	55.9 ^b	57.0 ^{a,b}	52.7 ^{a,b}	53.4 ^{a,b}	.009
% White	73.1	69.9 ^a	78.9 ^a	80.0 ^a	78.2 ^a	76.7 ^a	.021
Mean (SD) neighborhood income ^f	73.4 (34.0)	71.7 (34.1)	78.1 (34.0)	70.9 (29.5)	78.4 (37.0)	76.8 (34.7)	.076
Mean (SD) age	18.2 (.5)	18.2 (.5)	18.2 (.5)	18.2 (.5)	18.3 (.5)	18.2 (.5)	.433
% Smoked in lifetime	62.2	45.9 ^a	85.8 ^b	83.0 ^b	100.0 ^g	100.0 ^g	<.001
Mean (SD) number of years since first cigarette	3.2 (2.5)	3.2 (2.5) ^a	2.7 (2.3) ^a	2.9 (2.3) ^a	3.5 (2.3) ^{a,b}	4.1 (2.8) ^b	<.001
% Smoked in past month	24.2	1.9 ^a	49.5 ^b	41.0 ^b	90.9 ^c	93.2 ^c	<.001
Mean (SD) number of cigarettes per smoking day (among past-month smokers)	2.8 (3.4)	1.1 (.3) ^{a,c,d}	1.5 (1.4) ^{a,b}	1.5 (.7) ^{b,d}	3.5 (4.3) ^{c,e}	4.7 (4.3) ^c	<.001
% First cigarette <30 min after waking	4.1	0.0 ^g	1.1 ^a	0.0 ^g	6.0 ^a	8.5 ^a	.049
% Drank alcohol in past year	92.4	88.9 ^a	98.0 ^b	98.0 ^b	100.0 ^g	99.0 ^b	<.001
Mean (SD) number of drinks per drinking day (among past-year drinkers)	4.9 (2.7)	4.4 (2.5) ^a	5.4 (2.8) ^{b,c}	5.1 (2.3) ^{a,b}	6.1 (2.7) ^{b,c}	6.3 (3.4) ^c	<.001
% Alcohol dependent (among past-year drinkers)	15.9	12.3 ^a	18.2 ^{a,b}	18.6 ^{a,b}	25.5 ^{a,b}	28.4 ^b	<.001

Note. Pairwise comparisons were conducted only for variables for which the overall test statistic was statistically significant ($p < .05$).

^{a,b,c,d,e}Matching pairs of letters within each row denote comparisons that are not significantly different at $p < .05$, using Bonferroni correction.

^fThe mean adjusted gross income reported by the Internal Revenue Service for each participant's home ZIP code during their last year in high school, measured in 1000s.

^gDenotes categories that could not be compared because proportions were equal to zero.

frequent-intermittent smokers usually maintained high smoking levels (61.5% high-stable).

Association between Smoking Trajectory and Y₄ Health Outcomes

Table 3 presents results of the multiple regressions of the three health outcomes on the five smoking trajectory groups, holding constant sex, race, and neighborhood income. Smoking trajectory group membership significantly predicted Y₄ health rating, such that Y₄ health rating appeared to be closely related to Y₄ smoking pattern, regardless of which trajectory led to that smoking pattern. High-stable smokers (.28) and low-increasers (.20) had the highest probabilities of rating their health as fair/poor. The three groups with low levels of Y₄ smoking had low probabilities of rating their health as fair/poor (.11 for stable nonsmoking, .11 for low-stable, and .05 for high-decreasing), all of which were significantly lower than high-stable smokers. Thus, individuals who maintained their high-frequency smoking rated their health significantly worse than those who cut back by Y₄ (.28 vs. .05, $p < .05$). With respect to control variables, health ratings were significantly worse for nonWhites than Whites (.16 vs. .11, $p = .038$) and slightly but not significantly worse for males than females (.15 vs. .11, $p = .060$; data not shown in a table). None of the first-order interactions of race, sex, or neighborhood income with smoking trajectory were significant, nor was the main effect of neighborhood income.

In the regression of illness-related functional impairment on smoking trajectory group membership, again controlling for sex, race, and neighborhood income, no significant main effects were found for any of the control variables or smoking trajectory group membership, but the interaction of race with smoking trajectory group membership was significant ($p = .043$). In nonWhites, high-stable smokers had the most impairment (8.26 days), whereas in Whites, stable nonsmokers had the most impairment (6.10 days). Statistical significance was not attained in most of the pairwise comparisons.

Smoking trajectory group membership significantly predicted health service utilization, but only when its interaction with race was held constant. The interaction itself only approached statistical significance ($p = .101$) but was retained due to its apparent suppressor effect. In nonWhites, high-stable smokers had the most visits for health problems (4.45 visits), whereas in Whites, service utilization was not related to smoking trajectory group membership. With respect to the control variables, females had more visits for health problems than males (2.50 vs. 1.84, $p = .001$, data not shown in a table); neither race nor neighborhood income was significant.

Discussion

In this college student sample, five distinct smoking trajectories were identified on the basis of past-month smoking frequency

Table 2. Probability of Smoking Trajectory Group Membership, Given Year 1 Smoking Pattern (N = 1,253)

Year 1 smoking pattern	% (n) in smoking trajectory group						
	Number of smoking days in past month	% (n) of sample	Stable nonsmoking	Low-stable	Low-increasing	High-decreasing	High-stable
Non-smoker	0	75.8 (950)	81.7 (776)	10.8 (103)	6.2 (59)	0.5 (5)	0.7 (7)
Infrequent-intermittent	1–3	11.3 (142)	10.6 (15)	59.9 (85)	19.0 (27)	2.8 (4)	7.7 (11)
Moderate-intermittent	4–13	5.3 (66)	0.0 (0)	24.2 (16)	21.2 (14)	25.8 (17)	28.8 (19)
Frequent-intermittent	14–29	4.2 (52)	0.0 (0)	0.0 (0)	0.0 (0)	38.5 (20)	61.5 (32)
Daily	30	3.4 (43)	0.0 (0)	0.0 (0)	0.0 (0)	20.9 (9)	79.1 (34)

during the first 4 years of college: stable nonsmokers (71.5%_{wt}), low-stable smokers (13.3%_{wt}), low-increasing smokers (6.5%_{wt}), high-decreasing smokers (3.2%_{wt}), and high-stable smokers (5.5%_{wt}). Evidence for a stable pattern of intermittent (i.e., non-daily) smoking was found in the low-stable group, which experienced only a slight increase in mean smoking frequency (1.2–1.7 days/month). In most cases, individuals smoking 1–3 days/month in Y_1 (“infrequent-intermittent smokers”) maintained a low level of smoking throughout college (59.9%) but that likelihood declined inversely with Y_1 smoking frequency. For example, frequent-intermittent smokers (14–29 days/month) usually maintained a high level of smoking (61.5%), whereas moderate-intermittent smokers (4–13 days/month) were equally likely to differentiate into any of the four smoking trajectories (other than stable nonsmoking).

Daily smoking (3.4% overall, 14.2% of smokers) was less prevalent than in prior samples of young-adult smokers (Lenk et al., 2009; Nguyen & Shu, 2009), which is not surprising given our sampling design and prior evidence that smoking is less prevalent in college students than their nonstudent counterparts (White et al., 2009). Nevertheless, smoking trajectories predicted health outcomes. By Y_4 , high-stable smokers rated their health significantly worse than all other groups except low-increasers, consistent with prior longitudinal evidence based on smoking trajectories from ages 13–23 (Tucker, Ellickson, Orlando, Martino, & Klein, 2005). High-stable smokers experienced the most health problems, as measured by number of provider visits for health problems and number of days of illness-related impairment, but only among non-Whites. The observed differences in health outcomes might be attributable to the consequences of smoking, but we cannot rule out the possible influence of third factors associated with both smoking and health, such as heavy drinking, stress, negative affect (Magid, Colder, Stroud, & Nichter, 2009), and other possible health risk behaviors or mental health problems.

The finding that race moderated the relationship between smoking trajectory group membership and two health outcomes was unexpected given our low levels of smoking but is consistent with prior findings. Numerous studies have documented that Blacks are more vulnerable than Whites to the health effects of smoking in terms of slower nicotine metabolism (Perez-Stable, Herrera, Jacob, & Benowitz, 1998), greater susceptibility to nicotine dependence (Luo et al., 2008), and smoking-related lung cancer (Harris, Zang, Anderson, & Wynder, 1993). Future studies with larger samples should investigate whether race differences in the health effects of smoking exist even at low levels of smoking and elucidate the possible mechanisms underlying that

association, including the possible role of third factors not measured in this study such as race differences in attitudes about health-promoting behaviors, peer tobacco use, religiosity, social integration, and other risk factors for substance involvement (Juon et al., 2002; Wallace & Muroff, 2002).

Limitations and Strengths

Results must be interpreted in light of certain limitations. Self-report data are subject to recall bias, although this was likely minimized by focusing on very recent behavior (i.e., past-month smoking). Generalizability to other settings and geographic areas is unknown, especially given the sample’s homogeneity with respect to neighborhood income. Our income measure was based on participants’ neighborhood of residence immediately prior to college, rather than actual family income, and might not adequately represent socioeconomic status, which is a more complex construct. Past-month smoking might not be representative of smoking patterns throughout the rest of the year, such as weekday–weekend differences documented elsewhere (Colder et al., 2006). Although the overall sample size was large ($N = 1,253$), individual cell sizes for smoking trajectory group comparisons were not sufficient to detect significant differences, especially among nonWhites. Our self-report measures of health outcomes might be confounded by other personal factors such as differences in help-seeking and health-promoting behaviors and attitudes. No clinical data were available to verify the construct validity of our health outcome measures; nevertheless, the fact that we were able to detect modest differences in health outcomes—even at what for most individuals was a relatively early stage in their smoking career—points to the possibility that clinical health indicators might have differed even more dramatically between smoking trajectory groups. Although data were collected prospectively, no causal inferences can be made regarding the association between smoking and health outcomes. Data were not available to control for Y_1 health measures, and therefore we cannot rule out the possibility that the observed differences in health outcomes were attributable to preexisting health status—or other unidentified third variables. Whereas this study focused on predictors and outcomes measured concurrently with our first and last measure of smoking behavior (i.e., Y_1 and Y_4), future studies should examine even earlier influences on smoking trajectories and longer term health outcomes. Analyses did not account for variability in assessment timing, which spanned a 9-month interval corresponding to the academic year. However, follow-up assessments were scheduled within a few weeks of each individual’s Y_1 anniversary date.

The ability to examine temporal changes in smoking patterns is a unique strength of this study, as are the high follow-up rates

Table 3. Pairwise Comparisons of Health Outcomes at Year 4, by Smoking Trajectory Group (N = 1,090)

		Stable nonsmoking	Low-stable	High-decreasing	Low-increasing	High-stable	Overall p value
Probability of fair/poor health status		.11 (.01) ^a	.11 (.02) ^a	.05 (.03) ^a	.20 (.05) ^{a,b}	.28 (.05) ^b	<.001
Number of days limited due to illness ^c	NonWhite	3.71 (.49) ^a	4.23 (1.25) ^{a,b}	3.08 (1.73) ^{a,b}	1.35 (.67) ^b	8.26 (3.43) ^{a,b}	.022
	White	6.10 (.50) ^a	4.73 (.74) ^a	4.32 (1.40) ^a	4.05 (.88) ^a	3.52 (.78) ^a	.043
Number of visits for physical health problems ^d	NonWhite	2.59 (.26) ^a	1.66 (.40) ^{a,b}	1.98 (.87) ^{a,b}	1.00 (.41) ^b	4.45 (1.41) ^{a,b}	.005
	White	2.41 (.16)	1.84 (.23)	2.30 (.59)	2.36 (.41)	2.24 (.39)	.375

Note. Results reported as estimated marginal mean (SE), holding constant sex, race, and neighborhood income. Overall *p* reflects the chi-square test for the main effect of the smoking trajectory group variable.

^{a,b}Matching pairs of letters within each row denote comparisons that are not significantly different at $p < .05$, using Bonferroni correction.

^cThe first-order interaction of smoking trajectory group and race was statistically significant ($p = .043$); therefore, results are presented separately for Whites and nonWhites. The smoking trajectory group variable's main effect was not significant ($p = .114$).

^dThe first-order interaction of smoking trajectory group and race approached statistical significance ($p = .101$); therefore, results are presented separately for Whites and nonWhites. The smoking trajectory group variable's main effect was also significant ($p = .015$).

and large sample size. The use of count variables rather than the categorical ranges that have been used in many prior studies provides some analytic advantages, such as the flexibility to both model trajectories and define categories that are more nuanced than in prior studies (i.e., distinguishing between frequent-, moderate- and infrequent-intermittent smokers). Our empirically derived smoking trajectories support the notion that there are at least three types of intermittent smokers: those in transition to heavier patterns of use, those in transition to lighter patterns, and those capable of sustaining a low level of smoking for several years or longer. This finding supports and extends the work of other investigators who have speculated about the possible existence of stable light smoking patterns but were limited by cross-sectional designs and shorter or fewer follow-up intervals (Lenk et al., 2009; Wetter et al., 2004; White et al., 2009). Far from being a rarity, in our sample, the low-stable smoking pattern was the norm, outnumbering both increasers and high-stable smokers by 2:1 and decreasers by 4:1. Furthermore, by differentiating between frequent-, moderate- and infrequent-intermittent smokers, this study extends prior longitudinal evidence that intermittent smoking is less stable than nonsmoking and heavy smoking during young adulthood (Wetter et al., 2004; White et al., 2009). If replicated, results might indicate that less-than-weekly patterns of intermittent smoking are highly sustainable, whereas more frequent intermittent smoking is more transitional.

Implications

In the present study, low-stable smokers were indistinguishable from low-increasers with respect to Y_1 smoking patterns, thus raising questions about why smoking patterns escalated for some individuals while others were able to maintain a low level of smoking. White et al. (2009) identified binge drinking as a predictor of progressing to a heavier stage of smoking, yet we found no indication that Y_1 drinking was heavier among low-increasers relative to low-stable smokers, which parallels findings from another college student sample (Wetter et al., 2004). It is possible that the normative nature of heavy drinking among college students obscures any possible differences between smokers with and without an underlying susceptibility to developing nicotine dependence. Despite epidemiological evidence pointing to a shared genetic susceptibility for nicotine dependence and alcohol and other drug dependence (Compton, Thomas, Stinson, &

Grant, 2007; True et al., 1999), and other research documenting shared risk factors such as early conduct problems (Breslau, 1995), it remains unknown whether these associations hold true at lower levels of smoking. Future studies should focus on identifying predictors of escalation from intermittent smoking patterns and designing effective prevention strategies to help intermittent smokers cut back or quit. Whereas this study only considered the predictive value of Y_1 drinking, future studies with this cohort will examine the longitudinal interrelationships between changes in drinking and smoking behaviors during and after college.

Daily smoking and nicotine dependence were rare in this study. This finding is encouraging, and, if replicated, might indicate that prevention and policy initiatives to reduce heavy smoking—such as smoking restrictions on college campuses—have been successful. However, intermittent smoking patterns were almost as persistent as daily smoking but much more prevalent (13.3%_{wt} of students and 44% of smokers were low-stable smokers); thus, intermittent smokers are an important prevention target. Although intermittent smokers might be at low risk for nicotine dependence, long-term maintenance of a chronic pattern of light smoking could still have serious health consequences. Alcohol use, drug use, and social deviance have been associated with membership in any smoking trajectory group (Costello, Dierker, Jones, & Rose, 2008), and even light smoking has been linked to low birth weight and Apgar scores in infants born to adolescent smokers (Delpisheh, Attia, Drammond, & Brabin, 2006). In a large cohort study of Swedish men, both heavy and light smoking in late adolescence were associated with an increased risk of premature death (Neovius, Sundstrom, & Rasmussen, 2009).

Only a small proportion of the more frequent smokers cut back on their smoking during college. Based on anecdotal reports from our sample, we believe that for some students, the transition to college is an opportunity for a “fresh start,” in that they use the transition as a time to purposefully construct for themselves a new social environment that will support more positive choices and behaviors than in high school. This notion parallels empirical evidence from Chassin et al. (2000) that some adolescent smokers follow a distinct “experimenter” trajectory marked by rapidly declining use after age 17. Thus, it may be useful to design intervention strategies aimed directly at

incoming first-year college students in order to build on this naturally occurring “fresh start” mentality by increasing accessibility and visibility of programs and services that support tobacco cessation. Since formal smoking cessation programs might not be available at many universities, nontraditional outreach methods such as web-based programs and contingency management (Irons & Correia, 2008) should be evaluated for their effectiveness (Friedman, Smith, Zhang, Perry, & Colwell, 2004).

Supplementary Material

Supplementary Tables 1, 2, and 3 can be found online at <http://www.ntr.oxfordjournals.org>

Funding

This work was supported by the National Institute on Drug Abuse at the National Institutes of Health (R01-DA14845, Dr. Arria PI).

Declaration of Interests

None declared.

Acknowledgments

Special thanks are extended to Rebecca Baron, Lauren Stern, Emily Winick, the interviewing team, and the participants.

References

- American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders: DSM-IV*. (4th ed.). Washington, DC: American Psychiatric Press.
- Arria, A. M., Caldeira, K. M., O’Grady, K. E., Vincent, K. B., Fitzelle, D. B., Johnson, E. P., et al. (2008). Drug exposure opportunities and use patterns among college students: Results of a longitudinal prospective cohort study. *Substance Abuse*, 29, 19–38. doi:10.1080/08897070802418451
- Breslau, N. (1995). Psychiatric comorbidity of smoking and nicotine dependence. *Behavior Genetics*, 25, 95–101. doi:10.1007/BF02196920
- Chassin, L., Presson, C. C., Pitts, S. C., & Sherman, S. J. (2000). The natural history of cigarette smoking from adolescence to adulthood in a midwestern community sample: Multiple trajectories and their psychosocial correlates. *Health Psychology*, 19, 223–231. doi:10.1037//0278-6133.19.3.223
- Colder, C. R., Lloyd-Richardson, E. E., Flaherty, B. P., Hedeker, D., Segawa, E., & Flay, B. R. (2006). The natural history of college smoking: Trajectories of daily smoking during the freshman year. *Addictive Behaviors*, 31, 2212–2222. doi:10.1016/j.addbeh.2006.02.011
- Compton, W. M., Thomas, Y. F., Stinson, F. S., & Grant, B. F. (2007). Prevalence, correlates, disability, and comorbidity of DSM-IV drug abuse and dependence in the United States: Results from the National Epidemiologic Survey on alcohol and related conditions. *Archives of General Psychiatry*, 64, 566–576. doi:10.1001/archpsyc.64.5.566
- Costello, D., Dierker, L. C., Jones, B. L., & Rose, J. S. (2008). Trajectories of smoking from adolescence to early adulthood and their psychosocial risk factors. *Health Psychology*, 27, 811–818. doi:10.1037/0278-6133.27.6.811
- Delpisheh, A., Attia, E., Drammond, S., & Brabin, B. J. (2006). Adolescent smoking in pregnancy and birth outcomes. *European Journal of Public Health*, 16, 168–172. doi:10.1093/eurpub/cki219
- Friedman, K. E., Smith, D. W., Zhang, J. J., Perry, J., & Colwell, B. (2004). Importance of tobacco cessation services at higher education public institutions in Texas. *Journal of Drug Education*, 34, 313–325. doi:10.2190/T692-4M1J-JU8M-80CU
- Halperin, A., Smith, S. S., Heiligenstein, E., Brown, D., & Fleming, M. F. (2010). Cigarette smoking and associated health risks among students at five universities. *Nicotine & Tobacco Research*, 12, 96–104. doi:10.1093/ntr/ntp182
- Harris, R. E., Zang, E. A., Anderson, J. I., & Wynder, E. L. (1993). Race and sex differences in lung cancer risk associated with cigarette smoking. *International Journal of Epidemiology*, 22, 592–599. doi:10.1093/ije/22.4.592
- Hassmiller, K. M., Warner, K. E., Mendez, D., Levy, D. T., & Romano, E. (2003). Nondaily smokers: Who are they? *American Journal of Public Health*, 93, 1321–1327. doi:10.2105/AJPH.93.8.1321
- Heatherton, T. F., Kozlowski, L. T., Frecker, R. C., Rickert, W., & Robinson, J. (1989). Measuring the heaviness of smoking: Using self-reported time to the first cigarette of the day and number of cigarettes smoked per day. *British Journal of Addiction*, 84, 791–799. doi:10.1111/j.1360-0443.1989.tb03059.x
- Irons, J. G., & Correia, C. J. (2008). A brief abstinence test for college student smokers: A feasibility study. *Experimental and Clinical Psychopharmacology*, 16, 223–229. doi:10.1037/1064-1297.16.3.223
- Jones, B. L., Nagin, D. S., & Roeder, K. (2001). A SAS procedure based on mixture models for estimating development trajectories. *Sociological Methods and Research*, 29, 374–393. doi:10.1177/0049124101029003005
- Juon, H.-S., Ensminger, M. E., & Sydnor, K. D. (2002). A longitudinal study of developmental trajectories to young adult cigarette smoking. *Drug and Alcohol Dependence*, 66, 303–314. doi:10.1016/S0376-8716(02)00008-X
- Korhonen, T., Broms, U., Levalahti, E., Koskenvuo, M., & Kaprio, J. (2009). Characteristics and health consequences of intermittent smoking: Long-term follow-up among Finnish adult twins. *Nicotine & Tobacco Research*, 11, 148–155. doi:10.1093/ntr/ntn023
- Lenk, K. M., Chen, V., Bernat, D. H., Forster, J. L., & Rode, P. A. (2009). Characterizing and comparing young adult intermittent and daily smokers. *Substance Use and Misuse*, 44, 2128–2140. doi:10.3109/10826080902864571

- Levy, D. E., Biener, L., & Rigotti, N. A. (2009). The natural history of light smokers: A population-based cohort study. *Nicotine & Tobacco Research, 11*, 156–163. doi:10.1093/ntr/ntp011
- Luo, Z., Alvarado, G. F., Hatsukami, D. K., Johnson, E. O., Bierut, L. J., & Breslau, N. (2008). Race differences in nicotine dependence in the Collaborative Genetic study of Nicotine Dependence (COGEND). *Nicotine & Tobacco Research, 10*, 1223–1230. doi:10.1080/14622200802163266
- Magid, V., Colder, C. R., Stroud, L. R., & Nichter, M. (2009). Negative affect, stress, and smoking in college students: Unique associations independent of alcohol and marijuana use. *Addictive Behaviors, 34*, 973–975. doi:10.1016/j.addbeh.2009.05.007
- MelissaDATA. (2003). *Income tax statistics lookup*. Retrieved May 28, 2008, from <http://www.melissadata.com/lookups/taxzip.asp>
- Moran, S., Wechsler, H., & Rigotti, N. A. (2004). Social smoking among US college students. *Pediatrics, 114*, 1028–1034. doi:10.1542/peds.2003-0558-L
- Neovius, M., Sundstrom, J., & Rasmussen, F. (2009). Combined effects of overweight and smoking in late adolescence on subsequent mortality: Nationwide cohort study. *British Medical Journal, 338*, 635–638. doi:10.1136/bmj.b496
- Nguyen, Q. B., & Shu, S.-H. (2009). Intermittent smokers who used to smoke daily: A preliminary study on smoking situations. *Nicotine & Tobacco Research, 11*, 164–170. doi:10.1093/ntr/ntp012
- Perez-Stable, E. J., Herrera, B., Jacob, P., III., & Benowitz, N. L. (1998). Nicotine metabolism and intake in black and white smokers. *Journal of the American Medical Association, 280*, 152–156. doi:10.1001/jama.280.2.152
- Rock, V. J., Malarcher, A., Kahende, J. W., Asman, K., Husten, C., & Caraballo, R. (2007). Cigarette smoking among adults—United States, 2006. *Morbidity & Mortality Weekly Report, 56*, 1157–1161.
- SAS Institute Inc. (2008). *SAS 9.2*. Cary, NC: SAS Institute Inc.
- Substance Abuse and Mental Health Services Administration. (2003). *2002 National Survey on Drug Use and Health Questionnaire*. Office of Applied Studies, Substance Abuse and Mental Health Services Administration. Retrieved from <http://www.drugabusestatistics.samhsa.gov/nhsda/2k2MRB/2k2CAISpecs.pdf>
- Substance Abuse and Mental Health Services Administration. (2010). *Results from the 2009 National Survey on drug use and health: Volume I. Summary of National Findings*. Rockville, MD: Office of Applied Studies.
- Trinidad, D. R., Perez-Stable, E. J., Emery, S. L., White, M. M., Grana, R. A., & Messer, K. S. (2009). Intermittent and light daily smoking across racial/ethnic groups in the United States. *Nicotine & Tobacco Research, 11*, 203–210. doi:10.1093/ntr/ntp018
- True, W. R., Xian, H., Scherrer, J. F., Madden, P. A. F., Bucholz, K. K., Heath, A. C., et al. (1999). Common genetic vulnerability for nicotine and alcohol dependence in men. *Archives of General Psychiatry, 56*, 655–661. doi:10.1001/archpsyc.56.7.655
- Tucker, J. S., Ellickson, P. L., Orlando, M., Martino, S. C., & Klein, D. J. (2005). Substance use trajectories from early adolescence to emerging adulthood: A comparison of smoking, binge drinking, and marijuana use. *Journal of Drug Issues, 35*, 307–331. doi:10.1177/002204260503500205
- United States Department of Health and Human Services. (2010). *How tobacco smoke causes disease: The biology and behavioral basis for smoking-attributable disease: A report of the Surgeon General*. Atlanta, GA: Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health.
- Vincent, K. B., Kasperski, S. J., Caldeira, K. M., Garnier-Dykstra, L. M., Pinchevsky, G. M., O’Grady, K. E., et al. (2012). Maintaining superior response rates in a longitudinal study: Experiences from the College Life Study. *International Journal of Multiple Research Approaches, 6*, 56–72.
- Wallace, J. M. Jr., & Muroff, J. R. (2002). Preventing substance abuse among african american children and youth: Race differences in risk factor exposure and vulnerability. *Journal of Primary Prevention, 22*, 235–261.
- Waters, K., Harris, K., Hall, S., Nazir, N., & Waigandt, A. (2006). Characteristics of social smoking among college students. *Journal of American College Health, 55*, 133–139. doi:10.3200/JACH.55.3.133-139
- Wetter, D. W., Kenford, S. L., Welsch, S. K., Smith, S. S., Fouladi, R. T., Fiore, M. C., et al. (2004). Prevalence and predictors of transitions in smoking behavior among college students. *Health Psychology, 23*, 168–177. doi:10.1037/0278-6133.23.2.168
- White, H. R., Bray, B. C., Fleming, C. B., & Catalano, R. F. (2009). Transitions into and out of light and intermittent smoking during emerging adulthood. *Nicotine & Tobacco Research, 11*, 211–219. doi:10.1093/ntr/ntp017
- White, H. R., Johnson, V., & Buyske, S. (2000). Parental modeling and parenting behavior effects on offspring alcohol and cigarette use—A growth curve analysis. *Journal of Substance Abuse, 12*, 287–310. doi:10.1016/S0899-3289(00)00056-0
- White, H. R., Nagin, D., Replogle, E., & Stouthamer-Loeber, M. (2004). Racial differences in trajectories of cigarette use. *Drug and Alcohol Dependence, 76*, 219–227. doi:10.1016/j.drugalcdep.2004.05.004
- White, H. R., Pandina, R. J., & Chen, P.-H. (2002). Developmental trajectories of cigarette use from early adolescence into young adulthood. *Drug and Alcohol Dependence, 65*, 167–178. doi:10.1016/S0376-8716(01)00159-4
- Wortley, P. M., Husten, C. G., Trosclair, A., Chrismon, J., & Pederson, L. L. (2003). Nondaily smokers: A descriptive analysis. *Nicotine & Tobacco Research, 5*, 755–759. doi:10.1080/1462220031000158753