ELSEVIER

Smoking Trajectories of Adolescent Novice Smokers in a Longitudinal Study of Tobacco Use

IGOR KARP, MD, MPH, JENNIFER O'LOUGHLIN, PHD, GILLES PARADIS, MD, MSC, JAMES HANLEY, PHD, AND JOSEPH DIFRANZA, MD

PURPOSE: To describe longitudinal trajectories of smoking intensity in adolescent novice smokers and to identify predictors of trajectory class membership.
METHODS: Cigarette consumption among 369 novice smokers (mean age 13 years) was measured over a mean 24 months of follow-up after smoking onset. Classes of smoking intensity trajectories were identified using latent class growth modeling. Predictors of trajectory class membership were identified in polytomous logistic regression.
RESULTS: There was considerable between-subject heterogeneity in individual trajectories over time. Four classes of smoking intensity trajectories were identified: low-intensity, non-progressing smokers (72.4% of subjects), and slow, moderate, and rapid escalators (11.1%, 10.8%, and 5.7% of subjects, respectively). Gender, poor academic performance, and having more than half of friends who smoke at smoking onset independently predicted development of trajectory pattern. Escalating trajectory patterns were associated with earlier development of nicotine dependence and tolerance.
CONCLUSIONS: Cigarette consumption will not escalate rapidly among three-quarters of adolescent novice smokers. Novice smokers who do escalate rapidly should be targeted for early tobacco control intervention to prevent development of nicotine dependence and sustained smoking.
Ann Epidemiol ■. © 2005 Elsevier Inc. All rights reserved.

KEY WORDS: Cohort Studies, Linear Models, Tobacco, Smoking, Risk Factors, Adolescent.

INTRODUCTION

Adolescent smoking is an important public health problem because of its relation to adult tobacco consumption and because its prevalence has not declined in recent years to the same extent as that of adults. In fact, smoking prevalence in adolescents increased during most of the 1990s, raising concerns about future increases in adult smoking frequency, with concomitant rises in tobacco-related morbidity and mortality.

Although most adolescents try smoking, only about 25% will become regular smokers (1). It is largely unknown how smoking intensity and frequency evolve from the earliest smoking experience of youth to adult smoking levels. Understanding the early smoking patterns of novice adolescent smokers is important for identifying youth at risk of continued smoking and for developing more intensive and effective cessation interventions tailored to the needs of specific subgroups of smokers.

Several previous studies have investigated cigarette smoking trajectories in adolescents. Chassin et al. (2) identified six classes of trajectories in subjects aged 11 to 31 years using both an *a priori* classification method and empirical latent class growth modeling, including stable abstainers, erratic smokers, early stable and late stable smokers, quitters, and experimenters. Colder et al. (3) identified five classes of smoking patterns in subjects aged 11 to 16 years: early rapid escalators, late moderate escalators, late slow escalators, stable light smokers, and stable puffers. However, in both studies, the follow-up was anchored at an arbitrary time zero on the scale of age, and not at the time of smoking onset. In addition, the time intervals between follow-up measurements were wide, which might not have allowed for the necessary discriminatory power of the analytical techniques utilized.

The objective of this study was to identify longitudinal trajectories of smoking intensity in adolescent novice smokers, as well as personal characteristics related to specific trajectory patterns.

From the Department of Epidemiology and Biostatistics, Faculty of Medicine, McGill University, Montréal, Québec, Canada (I.K., J.O., G.P., J.H.); Division of Clinical Epidemiology, Montreal General Hospital, Montréal, Québec, Canada (I.K.); National Public Health Institute of Québec, Montréal, Québec, Canada (J.O., G.P); and Department of Family Medicine and Community Health, University of Massachusetts Medical School, Worcester, MA, USA (J.D.).

Address correspondence and reprint requests to: Dr. Igor Karp, Division of Clinical Epidemiology, Montreal General Hospital, 1650 Cedar Avenue, L-10, Montreal, Quebec H3G 1A4, Canada. Tel.: (514) 501-2796; Fax: (514) 934-8293. E-mail: igor.karp@mail.mcgill.ca

This research was funded by the National Cancer Institute of Canada, with funds from the Canadian Cancer Society. Igor Karp was supported by a Canadian Institutes for Health Research (CIHR) Fellowship. Jennifer O'Loughlin was a CIHR Investigator at the time this study was conducted and is currently the Canada Research Chair in the Childhood Determinants of Adult Chronic Disease.

Received June 15, 2004; accepted October 19, 2004.

360 Park Avenue South, New York, NY 10010

1047-2797/05/$–see front matter
doi:10.1016/j.annepidem.2004.10.002

Selected Abbreviations and Acronyms

NDIT = Natural History of Nicotine Dependence Study
BIC = Bayesian information criterion
SE = standard error
CI = confidence interval
OR = odds ratio

METHODS

Study Population

The McGill University Study on the Natural History of Nicotine Dependence (NDIT Study) is a 6-year (1999–2005) longitudinal study of 1293 students recruited from all grade 7 classes in a convenience sample of 10 Montreal secondary schools. The schools included a mix of French and English schools; urban, suburban, and rural schools; and schools located in high- and low-income neighborhoods. Over half (55.4%) of eligible students participated at baseline; the relatively low response rate was related to the need for blood draws for genetic analysis and to a labor dispute in Quebec that resulted in some teachers refusing to collect consent forms. Self-report questionnaires were administered every 3 to 4 months in the language of instruction of each school, either classroom by classroom or in the school cafeteria to groups of classes. Data from the first 3.5 years of follow-up were used in this current analysis so that each study subject had up to 14 questionnaires available for analysis.

Description of Study Variables

At each survey, participants provided data on cigarette smoking for each of the 3 preceding months, including the number of days on which they smoked each month and the average number of cigarettes smoked per day each month. These two measures were multiplied and averaged over each 3-month interval to produce an average monthly smoking intensity at each survey.

Psychosocial indicators. Worry or distress was measured in a 13-item scale measuring preoccupation with stressful life events in the past 3 months (4). Depression symptoms were measured in a validated 6-item scale (5–8). Self-esteem was ascertained in the Rosenberg 9-item scale (9). Novelty seeking was measured in a validated 9-item scale (8). Impulsivity was measured in a validated 7-item scale (10, 11). For each scale, responses were summed and divided by the number of items responded to, to create a continuous score for stress, depression, novelty-seeking, and impulsivity, respectively.

Indicators of nicotine dependence and tolerance. To create an indicator based on the six ICD-10 criteria for tobacco dependence (12), nicotine dependence-related questionnaire items were selected to measure each criterion. An item was considered positive only if the most extreme response choice was endorsed; a criterion was considered positive if the subject endorsed any of its items (the withdrawal syndrome required that two items be endorsed) (13). Time of conversion to nicotine dependence was defined to be the survey during which the subject first met three or more ICD-10 criteria.

Tolerance was measured by: Compared with when I first started smoking, I can smoke much more before I start to feel nauseated or ill (very true, a bit true, not at all true, I've never felt nauseated or ill from smoking). For analysis, time of conversion to tolerance was defined as the survey during which the subject first responded "very true."

Other potential predictors of smoking trajectory pattern investigated included sociodemographic characteristics [age, sex, and average household income, which was obtained from home address postal code data (14)], academic performance and confidence in one's abilities to succeed at school, and indicators related to smoking among peers (having more than half of friends smoking), at school (visibility of teachers and staff smoking at school, attending a school with a clear set of rules about smoking, attending a school where breaking rules causes trouble, attending a school where may students smoke where they are not allowed to), and in the family (parents smoking).

Statistical Analysis

Of the 1293 students in the study population, 480 (30%) initiated smoking during follow-up; 134 subjects (10%) reported smoking at baseline and 679 subjects (60%) never smoked and were thus excluded from analysis. In addition, of a total of 480 subjects who initiated smoking during the study period, we excluded 93 (25%) subjects whose trajectories could not be determined because they had fewer than three observations available for analysis; a further 18 (4%) subjects were excluded because their self-reports of smoking intensity were unreliable. Thus, 369 novice smokers were retained for analysis.

To identify longitudinal trajectories of smoking intensity beginning at time of onset we used individual growth modeling (15) and latent class growth analysis (16–19). First, a hierarchical linear model was fitted (20) to describe the overall pattern of smoking intensity over time and to examine between-subject variability in trajectories. Potential clustering by school was also considered in this analysis. Next, latent class growth analysis, and more specifically, semi-parametric group-based modeling (21), was used to identify major classes of trajectories. We considered 12 candidate models, allowing up to four underlying latent classes and up to a cubic polynomial function for each class. Model selection was based on the Bayesian Information

TABLE 1. Distributions of characteristics of subjects at smoking onset (n = 369)

Characteristic	Mean	Standard deviation	%
Age (years)	13.1	1.0	
Novelty-seeking score	3.1	0.9	
Impulsivity score	2.6	1.0	
Self-esteem score	2.4	0.4	
Depression score	2.3	0.7	
Stress score	1.6	0.5	
Annual family income (Canadian dollars)	61,919	22,567	
Male gender			35.2
Poor academic performance			19.1
Parents smoke			42.8
More than half of friends smoke			8.2
Teachers and staff smoke near school			81.5
Attends school with clear rules on smoking			81.2
Attends school where breaking smoking rules results in punishment			79.7
Attends school where many students smoke where they are not allowed to			77.6
Very confident in ability to succeed at school			82.3
At least one parent has university education			85.5

Criterion (BIC) (22) as a measure of goodness-of-fit. The hierarchical linear model was then fitted again, this time including covariates indicating trajectory class, as identified by the latent class growth analysis, and product-terms between trajectory class and growth parameters. This permitted quantification of between-subject heterogeneity remaining after accounting for smoking trajectory class. The associations between trajectory class and selected personal characteristics were examined using polytomous logistic regression (23, 24), which allows modeling dependent variables with more than two categories. Only variables statistically significant at the alpha level of 0.10 with trajectory class in univariate logistic regression analyses were included in the multivariable model. Finally, time to nicotine dependence and to tolerance across trajectory classes were compared using the Kaplan–Meier method (25), which allowed calculating cumulative incidence estimates within each class. All analyses were performed using SAS version 8.2 for Windows. (SAS Institute Inc., Cary, NC).

RESULTS

Table 1 describes selected characteristics of the 369 subjects retained for analysis. The average age at smoking onset was 13.1 years (range, 12.0–17.0). Two-thirds (64.8%) of the subjects were girls.

Initial Growth Curve Modeling Analysis

A series of hierarchical linear models were fitted with a random school-level intercept, a random subject-level intercept, and a random subject-level slope(s) for the effect

TABLE 2. Parameter estimates for fixed- and random-effects components for the initial and final hierarchical linear models

	Initial model		Final model	
Parameter	Estimate (SE)	*p*-value	Estimate (SE)	*p*-value
Fixed effects				
Intercept	17.99 (5.48)	0.0011	5.78 (4.47)	0.1973
Time[a]	13.26 (2.09)	< 0.0001	− 0.91 (1.97)	0.6423
Time^2 [a]	− 0.29 (0.20)	0.1521	0.13 (0.19)	0.5104
Trajectory class 1	–	–	0.00	
Trajectory class 2	–	–	18.97 (12.19)	0.1199
Trajectory class 3	–	–	11.00 (12.15)	0.3656
Trajectory class 4	–	–	178.23 (16.62)	< 0.0001
Time * Trajectory class 1	–	–	0.00	
Time * Trajectory class 2	–	–	− 7.34 (5.41)	0.1754
Time * Trajectory class 3	–	–	70.22 (5.07)	< 0.0001
Time * Trajectory class 4	–	–	115.99 (7.36)	< 0.0001
Time^2 * Trajectory class 1	–	–	0.00	
Time^2 * Trajectory class 2	–	–	3.23 (0.55)	< 0.0001
Time^2 * Trajectory class 3	–	–	− 4.52 (0.48)	< 0.0001
Time^2 * Trajectory class 4	–	–	− 6.91 (0.72)	< 0.0001
Random effects				
Between-subject variance in intercepts	6,447.43 (709.03)	< 0.0001	658.24 (171.65)	< 0.0001
Between-subject variance in slopes for time	445.72 (61.04)	< 0.0001	–	–
Between-subject variance in slopes for time^2	1.73 (0.49)	0.0002	0.28 (0.08)	0.0002
Residual variance	7,164.83 (238.75)	< 0.0001	7,495.17 (247.41)	< 0.0001

SE, standard error.
[a]Units for time: 3-month intervals since smoking onset.

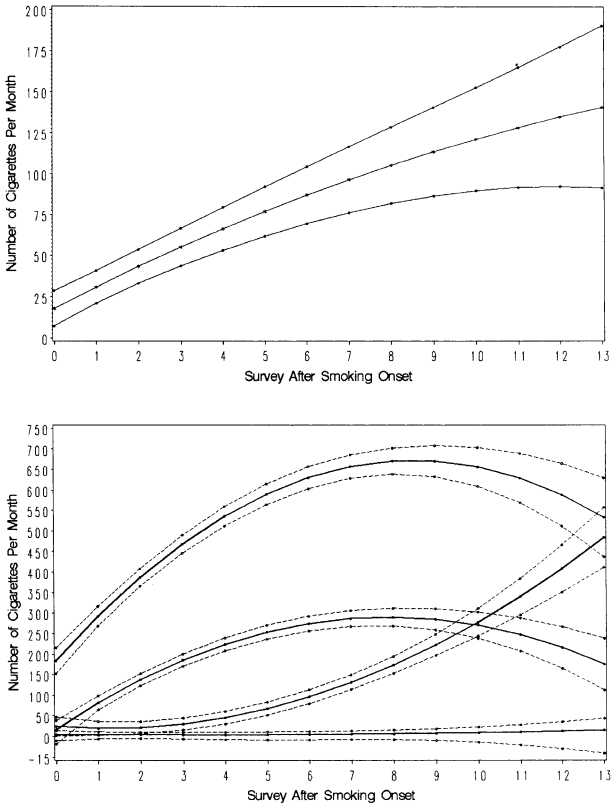

FIGURE 1. Overall trajectory of smoking intensity (top panel) and four classes of smoking intensity trajectories (bottom panel). Solid lines are point estimates, and dashed lines are the corresponding 95% confidence interval estimates. McGill University Study on the Natural History of Nicotine Dependence (NDIT), Montreal, Quebec, 1999–2002.

of time. Although the quadratic term for months since smoking onset was not statistically significant at the alpha level of 0.05, its addition to the model improved overall goodness-of-fit, compared with the model with only a linear term. The variation in intercepts between schools was not statistically significant at the alpha level of 0.05, so the random school-level intercept was removed. Higher-degree polynomial functions were considered but did not lead to substantial changes in the curve trajectory or goodness-of-fit compared with the quadratic polynomial function. Therefore the latter was retained as the initial model. The fixed- and random-effects estimates of parameters in the initial model are presented in Table 2. The model shows that, on average, subjects smoked 18 cigarettes per month in the period immediately following smoking onset. Consumption increased at a rate of 13.3 cigarettes per month every 3 months, with the rate of increase gradually decreasing over time (acceleration factor = −0.29) (Table 2). Figure 1 (top panel) shows the overall trajectory of smoking intensity across all subjects. Examination of random-effects parameter estimates for the growth curve model (Table 2) shows considerable between-subject variation in initial smoking intensity (the estimate of variance was 6447.43). In addition, there was substantial between-subject variation around both linear and quadratic components of the trajectories (the estimates of variances were 445.72 and 1.73, respectively).

Latent Class Growth Analysis

We selected a quadratic polynomial growth mixture model with four smoking trajectory classes as the final model because this model had the lowest BIC. Class I, II, III and IV included 267 (72.4 %), 41 (11.1 %), 40 (10.8 %), and 21 (5.7%) subjects, respectively.

Growth Curve Modeling Analysis Accounting for Class Membership

When the growth curves incorporating both main effects for trajectory class and product-terms between trajectory class and growth parameters were fitted, the random-effect component for the linear term for the effect of time was negligible. Therefore the final model contained only random effects for the subject-level intercept and for the acceleration rate parameter (Table 2). The plots of the fitted smoking intensity values for the four trajectories (along with the corresponding 95% confidence intervals) are shown in Fig. 1 (bottom panel). Subjects in class I were characterized by low cigarette consumption at smoking onset (approximately six cigarettes per month). Smoking intensity gradually increased. However, because of the slow rate of acceleration over time, subjects in class I consumed only 15 cigarettes per month after 39 months of follow-up. Subjects in classes II and III also began smoking at low intensities (25 and 17 cigarettes per month, respectively), but the trajectory in class II increased exponentially over time, so that after 39 months of follow-up they consumed approximately 485 cigarettes per month. The trajectory of class III subjects followed a parabolic shape, with the peak intensity attained 2 years after smoking onset. The overall shape of the trajectory in class IV was similar to that of class III. However, subjects in class IV began smoking at relatively high intensities (184 cigarettes per month). The peak intensity was attained 2 years after smoking onset (671 cigarettes per month), after which there was an apparent decline in smoking intensity. At the end of 39 months of follow-up, the average level of smoking declined to 534 cigarettes per month.

Comparing the variance components in the final hierarchical linear model with those from the initial hierarchical linear model without covariates for trajectory class (Table 2), revealed that classification of subjects into four classes led to a considerable reduction in population

TABLE 3. Patterns of smoking intensity in relation to characteristics measured at smoking onset[a]

	Class I	Class II	Class III	Class IV	
Characteristic	OR	OR	OR	OR	*p*-value
Age (per year)	1.00	0.50	0.61	1.77	0.0816
Gender					
Male	1.00	0.62	0.49	1.88	0.0724
Female[b]					
Poor academic performance					
Yes	1.00	1.46	4.33	5.86	0.0007
No[b]					
Parents smoke					
Yes	1.00	1.39	1.64	2.22	0.0167
No[b]					
More than half of friends smoke					
Yes	1.00	1.93	6.40	12.11	< 0.0001
No[b]					
Teachers and staff smoke near school					
Yes	1.00	1.14	1.04	2.62	0.8275
No[b]					
Attends school with clear rules on smoking					
Yes	1.00	0.66	0.27	0.56	0.0510
No[b]					
Attends school where breaking smoking rules results in punishment	1.00	0.88	0.40	2.56	0.1298
Yes					
No[b]					
Attends school where many students smoke where they are not allowed to	1.00	1.10	0.85	3.28	0.6895
Yes					
No[b]					
Very confident in ability to succeed at school					
Yes	1.00	0.42	0.37	0.83	0.0641
No[b]					
At least one parent has university education					
Yes	1.00	1.30	0.53	0.40	0.4493
No[b]					
Novelty-seeking (per 1 unit)	1.00	1.46	0.64	1.19	0.6268
Impulsivity (per 1 unit)	1.00	1.39	1.51	0.66	0.5576
Self-esteem (per 1 unit)	1.00	0.31	0.64	1.72	0.4654
Family income (per 5000 Canadian dollars)	1.00	0.90	0.88	0.77	0.3095
Depression (per 1 unit)	1.00	1.06	1.99	0.86	0.5004
Stress (per 1 unit)	1.00	2.79	2.79	0.67	0.2696

OR, odds ratio.
[a]Polytomous logistic regression analysis using class I as the reference category.
[b]Reference category.

heterogeneity in the growth parameters. In particular, the variance of subject-level intercept was 658.24, compared with 6447.43 in the initial model. Similarly, the variance around the subject-level rate of acceleration was 0.28, compared with 1.73 in the initial model.

Predictors of Smoking Trajectory Class Membership

Table 3 shows unadjusted associations between subjects' characteristics measured at smoking onset and trajectory class; class I served as the reference category. Family income did not appear to be an important predictor of trajectory class. Older age showed a moderately strong negative association with trajectory classes II and III, but a positive association with class IV. Males were slightly less likely than females to develop classes II and III, but more likely to develop a class IV trajectory. Having parents who smoke and more than half of friends smoking were statistically significant predictors of the three escalating patterns. Attending a school with a clear set of rules on smoking was negatively associated with the escalating trajectory patterns. Visibility of teachers and staff smoking near school and attending a school where many students smoke where they are not allowed to, were positively associated with trajectory pattern. Poor academic performance showed a strong positive association with trajectory pattern. Among the other psycho-social characteristics investigated, only having confidence in one's abilities to succeed at school

TABLE 4. Adjusted associations of characteristics measured at smoking onset with specific patterns of smoking intensity[a]

	Class II		Class III		Class IV		
Characteristic	Adjusted OR	95% CI	Adjusted OR	95% CI	Adjusted OR	95% CI	*p*-value
Age (per year)	0.63	0.27, 1.49	1.50	0.55, 4.08	2.04	0.51, 8.16	0.4129
Gender							
Male	0.48	0.19, 1.16	0.24	0.06, 0.88	1.84	0.49, 6.85	0.0355
Female[b]							
Poor academic performance							
Yes	1.67	0.62, 4.49	3.96	1.38, 11.40	7.26	1.77, 29.77	0.0066
No[b]							
Parents smoke							
Yes	1.15	0.52, 2.52	2.04	0.77, 5.42	4.94	1.13, 21.53	0.1071
No[b]							
More than half of friends smoke							
Yes	1.72	0.31, 9.60	10.18	2.59, 40.56	7.58	1.27, 45.30	0.0053
No[b]							
Attends school with clear rules on smoking							
Yes	0.91	0.28, 2.90	0.26	0.08, 0.78	0.84	0.09, 7.78	0.1205
No[b]							
Very confident in ability to succeed at school							
Yes	0.50	0.20, 1.23	0.68	0.23, 2.05	1.30	0.13, 4.48	0.4324
No[b]							

OR, odds ratio; CI, confidence interval.
[a]Polytomous logistic regression analysis using class I as the reference category. Maximum-rescaled $R^2 = 0.25$.
[b]Reference category.

suggested a non-trivial association with the outcome. Based on the univariate analysis, seven potential predictors of trajectory class were retained for multivariable analysis.

Table 4 describes the independent predictors of trajectory class, identified in multivariable analysis. The effect of gender, although statistically significant, was ambiguous: boys were less likely than girls to develop class II and III trajectories, but more likely to develop a class IV trajectory. Poor academic performance and having more than half of friends smoking were strong risk indicators for developing the escalating trajectory patterns. The point estimates of the parameters for the effect of having parents smoking were also suggestive of a positive association with the probability of developing an escalating trajectory pattern, but their corresponding 95% confidence intervals were too wide to allow meaningful interpretation. Similarly imprecise results were obtained for attending a school with a clear set of rules on smoking and having confidence in one's abilities to succeed at school, although the point estimates were generally consistent with the protective role of these characteristics. The results of estimating the effect of age were also inconclusive, although the parameter estimates suggested potentially positive associations between older age and trajectory classes III and IV.

Development of Nicotine Dependence and Tolerance during Follow-up

Figure 2 shows the "survival" curves for the development of nicotine dependence (top panel) and tolerance (bottom panel) within each trajectory class. Only 12% of subjects in class I developed nicotine dependence during follow-up, while the percentages in classes II, III, and IV were 79, 79, and 95, respectively (p-values for the three comparisons were all < 0.0001).

Twenty-one percent of subjects in class I developed tolerance; the percentages were 81, 87, and 95, in classes II, III, and IV, respectively (p-values for the three comparisons were all < 0.0001).

DISCUSSION

The goals of our study were to identify longitudinal trajectories of smoking intensity in adolescent novice smokers, to identify predictors of trajectory pattern, and to explore the development of nicotine dependence and tolerance in relation to trajectory pattern. The overall trajectory pattern in novice smokers can be described by a curve based on a quadratic polynomial function. Traditional growth modeling, based on the presumption of a single underlying growth process, was supplemented by latent class growth modeling to enable identification of distinct longitudinal smoking intensity patterns. We identified four major classes of trajectories; the majority (72.4%) of subjects fell into the class of low-intensity, non-progressing smokers. The other three classes were characterized by differing patterns of smoking intensity escalation. Identification of discrete classes of trajectories led to considerable reduction in between-subject heterogeneity

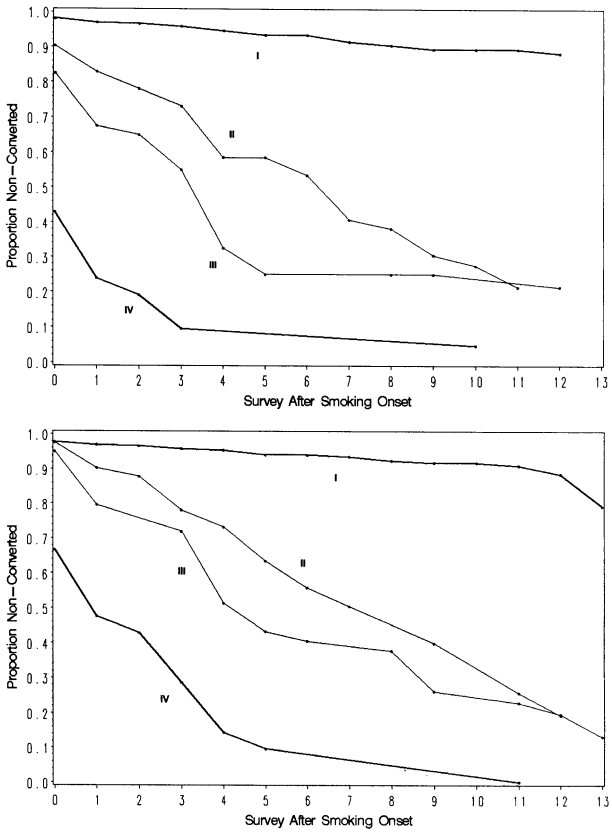

FIGURE 2. Kaplan–Meier plots comparing time to the development of nicotine dependence (top panel) and tolerance (bottom panel) in the four smoking intensity trajectory classes. McGill University Study on the Natural History of Nicotine Dependence (NDIT), Montreal, Quebec, 1999–2002.

in smoking intensity and provided insight regarding longitudinal patterns of cigarette consumption in novice smokers. Our data suggest that, among young adolescents who initiate tobacco use, approximately one-third is at risk of escalating relatively quickly to higher levels of consumption.

Previous data from this and other studies indicate that symptoms of nicotine dependence can begin soon after the onset of smoking (26–29). The measure of tobacco dependence used in this study was not designed to detect the first symptoms of dependence, because a determination of dependence was not made until at least three symptoms were present. Nevertheless, a large majority of youth who escalated tobacco use were dependent even according to these more conservative criteria, and conversely, few subjects who maintained low levels of cigarette use were dependent after months of follow-up. Interventions that are intended to prevent the escalation of tobacco use among intermittent users may need to address this issue of early dependence.

Predictors of developing a particular smoking intensity trajectory pattern included poor academic performance and having more than half of friends smoking. Male gender was negatively associated with the probability of developing classes II and III trajectories, while its role with respect to class IV trajectory was unclear. Age, parental smoking, attending a school with a clear set of rules on smoking, and having confidence in one's abilities to succeed at school were possibly related to trajectory pattern but the results were inconclusive due to insufficient precision of the results. While our results confirm the findings of many previous studies on factors associated with early smoking in youth (30), it is intriguing that attending a school with a clear set of rules on smoking emerged as a potential predictor. Many past tobacco control programs for youth have been targeted to the individual, based on his/her individual characteristics. However, interest has increased recently in programs targeted to the physical and social environments, because these interventions might have broader reach in terms of influencing social norms. Our results suggest that programs that emphasize school smoking policies could be important in youth tobacco control.

Study limitations include a relatively small sample size. One consequence of this was a high degree of uncertainty in estimating exact trajectory patterns, especially at the end of the trajectory curves. In particular, while the point estimates for trajectories in classes III and IV suggested declines at the end of the trajectory curves, their corresponding upper 95% confidence bounds were, in fact, compatible with a leveling-off pattern. Missing data on smoking frequency and/or amount smoked might have resulted in misclassification of trajectory class membership. However, the posterior probabilities of class membership within each class were notably divergent, indicating a high degree of accuracy in the assignment to a particular class (in particular, the minimum, maximum, and median values for the posterior probabilities of class membership within each class were: 0.49, 1.00, 0.99 for class I, 0.42, 1.00, 0.94 for class II, 0.41, 1.00, 0.96 for class III, and 0.91, 1.00, 1.00 for class IV, respectively). Although the baseline response rate was relatively low, non-response is unlikely to have resulted in bias in describing trajectory classes or in identifying predictors of trajectory class. Finally, in the analysis of predictors of smoking intensity trajectory patterns, we did not examine potential interactions between individual predictors in order to reduce the possibility of overfitting the model.

In conclusion, our study suggests that there are four distinct patterns of longitudinal smoking intensity trajectories among novice adolescent smokers. The development of these patterns is associated with gender, school performance, peer smoking, and possibly a number of other sociodemographic and psychosocial indicators. Subjects

with escalating smoking intensity were characterized by earlier development of nicotine dependence and tolerance compared with those with non-escalating patterns. Identification of specific trajectories might be helpful to tobacco control practitioners in designing programs tailored to the specific needs of novice smokers at higher risk of developing nicotine dependence and sustained smoking.

The authors thank Elizabeth McMillan-Davey for her contributions. They also thank the staff and students in participating schools.

REFERENCES

1. Centers for Disease Control and Prevention. Selected cigarette smoking initiation and quitting behaviors among high school students—United States, 1997. MMWR Morb Mortal Wkly Rep. 1998;47:386–389.
2. Chassin L, Presson CC, Pitts SC. The natural history of cigarette smoking from adolescence to adulthood in a Midwestern community sample: Multiple trajectories and their psychological correlates. Health Psychol. 2000;19:223–231.
3. Colder CR, Mehta P, Balanda K, Campbell RT, Mayhew KP, Stanton WR, et al. Identifying trajectories of adolescent smoking: An application of latent growth mixture modeling. Health Psychol. 2001;20:127–135.
4. Deschesnes M. Style de vie des jeunes du secondair en Outaouais [Life style of youth in secondary schools in Outaouais]. Tome 1 (Secteur general). [Chapter 1]. Hull, Quebec, Canada: Direction de la sante publique. Regie regionale de la sante et des services sociaux. [Public Health Directorate, Regional Directorate of Health and Social Services]; 1997:150.
5. Choi WS, Pierce JP, Gilpin EA, Farkas AJ, Berry CC. Which adolescent experimenters progress to established smoking in the United States. Am J Prev Med. 1997;13:385–391.
6. Zhu SH, Sun J, Billings SC, Choi WS, Malarcher A. Predictors of smoking cessation in US adolescents. Am J Prev Med. 1999;16:202–207.
7. Escobedo LG, Reddy M, Giovino GA. The relationship between depressive symptoms and cigarette smoking in US adolescents. Addiction. 1998;93:433–440.
8. Kandel DB, Davies M. Epidemiology of depressive mood in adolescents. Arch Gen Psychiatry. 1982;39:1205–1212.
9. Vallieres EF, Vallerand R. Traduction et validation canadienne-francaise de l'echelle de l'estime de soi de Rosenberg [Translation to French (Canadian) and validation of Rosenberg's self-esteem scale]. Int J Psychol. 1990;25:305–316.
10. Wills TA, Windle M, Cleary SD. Temperament and novelty seeking in adolescent substance use: Convergence of dimensions of temperament with constructs from Cloninger's theory. J Pers Soc Psychol. 1998;24:387–406.
11. Eysenck SBG, Eysenck HJ. The place of impulsiveness in a dimensional system of personality description. Br J Soc Clin Psychol. 1977;16:57–68.
12. World Health Organization. International Statistical Classification of Diseases and Related Health Problems, 10th revision Geneva: WHO; 1992.
13. O'Loughlin J, DiFranza J, Tarasuk J, Meshefedjian G, McMillan-Davey E, Paradis G, et al. Assessment of nicotine dependence symptoms in adolescents: a comparison of five indicators. Tob Control. 2002;11:354–360.
14. Statistics Canada. Canada Census 1996. 1996. Available at: http://www12.statcan.ca/english/census01/info/census96.cfm. Accessed May 26, 2004.
15. Raudenbush SW, Bryk AS. Hierarchical linear models: Applications and data analysis methods. Thousand Oaks, CA: Sage Publications; 2002.
16. Nagin DS. Analyzing developmental trajectories: A semi-parametric, group-based approach. Psychol Methods. 1999;4:139–157.
17. Muthen B, Muthen L. Integrating person-centered and variable-centered analysis: Growth mixture modeling with latent trajectory classes. Alcohol Clin Exp Res.. 2000;24:882–891.
18. Roeder K, Lynch KG, Nagin DS. Modeling uncertainty in latent class membership: A case study in criminology. J Am Stat Assoc. 1999;94:766–776.
19. Nagin D, Tremblay R. Trajectories of boys' physical aggression, opposition, and hyperactivity on the path to physically violent and nonviolent juvenile delinquency. Child Dev. 1999;70:1181–1196.
20. Singer JD. Using SAS PROC MIXED to fit multilevel models, hierarchical models, and individual growth curve models. J Educ Behav Stat. 1998;24:343–355.
21. Jones BL, Nagin DS, Roeder K. A SAS procedure based on mixture models for estimating developmental trajectories. Sociol Meth Res. 2001;29:374–393.
22. Schwarz G. Estimating the dimension of a model. Ann Stat. 1978;6:461–464.
23. Stokes ME, Davis CS, Koch GG. Categorical data analysis using the SAS system. Cary, NC: SAS Institute Inc; 1995.
24. Agresti A. Categorical data analysis. New York, NY: John Wiley and Sons; 1990.
25. Kaplan EL, Meier P. Nonparametric estimation from incomplete observations. J Am Stat Assoc. 1958;53:457–481.
26. DiFranza JR, Rigotti NA, McNeill AD, Ockene JK, Savageau JA, St Cyr D, et al. Initial symptoms of nicotine dependence in adolescents. Tob Control. 2000;9:313–319.
27. DiFranza JR, Savageau JA, Fletcher K, Ockene JK, Rigotti NA, McNeill AD, et al. Measuring the loss of autonomy over nicotine use in adolescents: The DANDY (Development and Assessment of Nicotine Dependence in Youths) Study. Arch Pediatr Adolesc Med. 2002;156:397–403.
28. DiFranza JR, Savageau JA, Rigotti NA, Fletcher K, Ockene JK, McNeill AD, et al. Development of symptoms of tobacco dependence in youths: 30 months of follow up data from the DANDY study. Tob Control. 2002;11:228–235.
29. O'Loughlin J, DiFranza J, Tyndale R, Meshefedjian G, McMillan-Davey E, Clarke PB, et al. Nicotine dependence symptoms are associated with smoking frequency in adolescents. Am J Prev Med. 2003;25:219–225.
30. US Department of Health and Human Services. Preventing tobacco use among young people: A report of the Surgeon General. Atlanta, Georgia: US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health; 1994.