

Trajectories of smokeless tobacco use and of cigarette smoking in a cohort of Swedish adolescents: Differences and implications

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Developmental trajectories of cigarette smoking have often been described, but there are no such analyses dealing with smokeless tobacco use. A semi-parametric group-based mixture modeling procedure was used to determine the development of smokeless tobacco (snus) use, as well as of cigarette smoking, over time in a cohort of 2,175 Swedish adolescents who were never-users of tobacco at the time of recruitment. An indicator of snus and of cigarette consumption in the previous year was used to model the development of the behavior between 11 and 18 years of age. For snus use three trajectories best described the cohort's experience, while four trajectories provided the best description of cigarette smoking in the cohort. For both tobacco types there were two escalation patterns and one *sustained trial* trajectory, while an extinction pattern was apparent for cigarette smoking only. Marked sex differences were found, since rapid escalation for snus use was found only among males while high consumption of cigarettes was observed only among females. Dual users (54.9% of all users) showed a trajectory of steeper and more prolonged increase of tobacco consumption than exclusive users of either snus or cigarettes. Several risk factors for tobacco use measured at baseline influenced individual probabilities of belonging to a particular trajectory. The developmental patterns of snus use and cigarette smoking showed high similarity, but they evolved differently in the two sexes. Dual users emerged as a high-risk group for tobacco dependence and tobacco-related harms.

Introduction

Identifying the course of a particular health behavior over time (developmental trajectory) is essential in order to better understand its natural history, as well as to identify targets for change or prevention (Colder et al., 2001). This is especially important when there is empirical evidence that the development of a particular behavior is not homogeneous within a given population. Tobacco use, perhaps the

single most important factor for future morbidity and premature death, is typically initiated at a young age, but many adolescents do not progress beyond early experimentation (Centers for Disease Control and Prevention, 1994). Several studies have identified smoking trajectories in adolescence (Chassin, Presson, Pitts, & Sherman, 2000; Colder et al., 2001; Karp, O'Loughlin, Paradis, Hanley, & Difranza, 2005; Orlando, Tucker, Ellickson, & Klein, 2004; Stanton, Flay, Colder, & Mehta, 2004), while to date there are no studies describing trajectories of smokeless tobacco use. In Sweden, a declining smoking trend in the general population occurred concomitantly with increasing use of snus (moist oral snuff, the Swedish variety of smokeless tobacco), at least in the male population. Increasing trends of snus use have recently been observed also among young girls (Hvitfeldt, Rask, Andersson, & Hibell, 2005). The present study, based on a prospective cohort of adolescents, had two aims. First, we wanted to describe and compare

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developmental trajectories of snus use, cigarette smoking and dual use of tobacco at young ages. Second, we wanted to explore whether well-established risk factors for tobacco use were also modifiers of the developmental profiles of snus and cigarette use.

Method

Subjects

The BROMS (Swedish acronym for Children's Smoking and Environment in the Stockholm County) cohort encompasses 3,020 children recruited in 1997, at the time they attended the 5th grade of the compulsory school. After parental consent, 3,050 students (65.3% of all those eligible) were contacted for the baseline survey, and 3,030 (99.0%) participated. Details on the recruitment of the cohort and on participants' characteristics have been described previously (Galanti, Rosendahl, Post, & Gilljam, 2001; Post, Galanti, & Gilliam, 2003). The adolescents were followed up to the age of 18 years (i.e. 3 years after leaving the compulsory school). Retention of the cohort members was high, since only 6.4% of the sample participated in three or less of the six follow-up surveys, while as many as 68.8% participated in all of them. Students reporting having used tobacco ($n=608$, 20.1%), or with missing information on tobacco use ($n=15$, 0.5%) at baseline, were not included in this study. Furthermore, never-users of tobacco during the whole study period ($n=222$, 7.4%) were also excluded from the analysis, since the trajectory for never-users is intuitive and does not need to be modeled. The analytical sample for this study consisted of 2,175 adolescents, 1,091 boys and 1,084 girls, with a mean age of 11.6 years ($SD=0.33$) at baseline, who were never-users of tobacco at baseline and initiated tobacco use sometime during follow-up. Mean age at the end of follow-up was 18.6 ($SD=0.33$) among adolescents who provided information on tobacco use ($n=1,818$) at the last survey.

Data collection

A survey was conducted every year (with the exception of the first year after compulsory school) starting from the 5th grade (baseline). A self-administered questionnaire was answered in the classroom up to the end of compulsory grades (9th grade), and at each subject's home thereafter. Separate and very similar questions were employed for the use of snus and cigarettes, respectively. Because of this similarity we only report the questions on snus use (response alternatives within parentheses). "Did you ever try snus?" (yes/no). "Did you use snus more than once?" (yes/no). "How many

times altogether did you use snus in your life?" (1–4, 5–9, ≥ 10). "Do you currently use snus?" (not at all; occasionally, less than monthly; monthly, but not weekly; weekly, but not daily; daily). "For how long have you been using snus, altogether?" (<3 months, 3–6 months, 6–12 months, 1–2 years, >2 years). "How many times do you (or did you, if you quit), usually use snus during a week?" (open response alternative). The questionnaire also included one question about number of friends using snus or cigarettes (none, 1, 2, 3, 4, >4). Information on parents' occupation, education, and history of tobacco use was collected at baseline through a parents' survey (99.5% responders). School and class prevalence of lifetime tobacco use at baseline was calculated by dividing the number of students who had reported positively to ever-use of cigarettes and/or snus by the total number of participating students in each school or class.

Data analysis and statistical methods

The behavioral outcome used to model the developmental trajectories was the estimated number of snus dips, cigarettes, or both snus dips and cigarettes combined, consumed during each survey interval, categorized into five categories for snus dips and for combined use of snus and cigarettes (0, 1–9, 10–35, 36–363, >363), and six categories for cigarette smoking (0, only a few puffs, 1–9.5, 10–35.5, 36–363.5, >363.5). Only a few puffs were treated as one use in the categorization of combined use of snus and cigarettes. In the survey instrument there were no direct questions on number of snus dips or number of cigarettes during the previous year, therefore these quantities were estimated from the other questions on number of times used, current use and duration of use. For subjects reporting daily or weekly use of snus or cigarettes, the annual number of snus dips or number of cigarettes was estimated with reference to the fraction of the year, assuming the consumption as constant. For those reporting monthly, but not weekly use, a consumption of three snus dips or cigarettes per month was assumed. Missing answers at any wave were replaced with a zero, in case the subject subsequently reported never use. In all other instances, missing values were treated as missing in the analysis. We modeled the trajectories for use of snus and for cigarette smoking as separate and independent behaviors, as well as by subgroups of exclusive users of either snus ($n=76$) or cigarettes ($n=510$), and of dual users of both tobacco types ($n=1,195$). The developmental trajectories were identified by means of a semi parametric group-based approach (Nagin, 1999). This modeling approach has been used to identify distinct clusters of behaviors, such as conviction for criminal offenses

and history of cigarette smoking. The SAS (SAS Institute Inc., Cary, NC, USA) procedure TRAJ (Jones, Nagin, & Roeder, 2001) has been developed to estimate the number of groups that best fits the data, as well as the shape of the trajectory for each group (it is allowed to specify up to a third-order polynomial in time/age), using all longitudinal information. The selection of the best model is primarily based on the Bayesian information criterion (BIC) where the maximum BIC corresponds to the least negative value. BIC was used in the model selection in order to: (a) determine the optimal number of groups describing the developmental history, (b) identify the covariates to be included in the model, and (c) determine the appropriate order of the polynomial used to model each group's trajectory. An approximation of the Bayes factor was used to test whether the model was essentially improved by additional parameters. The model also estimates the proportion of the whole population whose behavioral changes over time most closely conform to each trajectory group. Finally, the model computes the individual probability of belonging to each of the identified trajectories. Since the outcome of interest was a count, both ordinary Poisson and zero-inflated Poisson (ZIP) distributions were used in the models. The ZIP distribution is useful for modeling the conditional distribution of count data when there is over-dispersion (Lambert, 1992). In order to assess the reliability of the modeled group membership we tested whether some well-known predictors of tobacco use, with information collected at baseline, could predict posterior group membership probabilities. These factors were: parents' tobacco use, friends' tobacco use, parents' education, prevalence of lifetime tobacco use in class and school, age and sex. As an indicator of parents' education we used primarily mother's education (Rosendahl, Galanti, Gilljam, & Ahlbom, 2003). Parents' and friends' tobacco use and parents' education were all analyzed dichotomously (at least one user of tobacco vs. no users of tobacco, college level vs. lower than college level education).

Results

When snus use and cigarette smoking were considered as separate and independent behaviors, a model with three developmental trajectories among ever users was found to provide the best fit for snus use, while four groups gave the best fit for cigarette smoking when data for both sexes were analyzed together. By simultaneously including into the model parents' education, parents' tobacco use, friends' tobacco use, and gender as covariates, the fit of the model-based trajectories for cigarette use was improved, with a strong superiority of the alternative

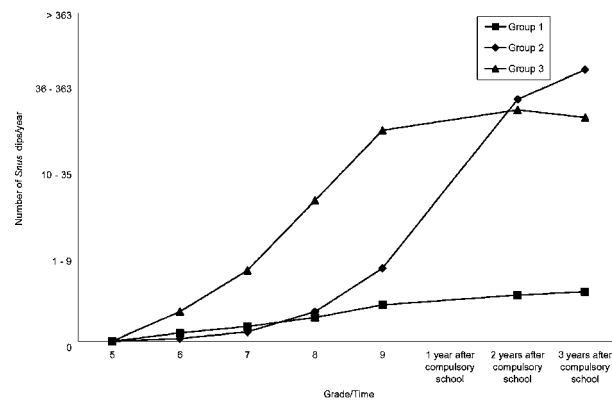


Figure 1. Trajectories of snus use among males, the BROMS Cohort Study, 1998–2005.

(more complex) model. Parents' education and friends' tobacco use did not improve the model for snus use. Prevalence of lifetime tobacco use in class and school at baseline, and age, did not improve the model for either tobacco product. Since the prevalence of use of snus and cigarettes differ substantially between the males and females the trajectories for each tobacco product are presented separately by sex (Figures 1 and 2 describe snus use while 3 and 4 describe cigarette smoking among males and females respectively).

The trajectories for snus use among males could be described as follows:

1. *Sustained trial*: ($n=452$, 41.4% of males in the cohort). Median probability of group membership=95.4 (25th and 75th percentiles, 85.4 and 98.5, respectively). On average, subjects in this group never escalated their annual consumption beyond the level of testing.
2. *Late escalation*: ($n=169$, 15.5% of males in the cohort). Median probability of group membership=82.4 (25th and 75th percentiles, 64.7 and 89.4, respectively). The group showed experimental behavior up to the end of compulsory school (9th grade), thereafter a rapid increase

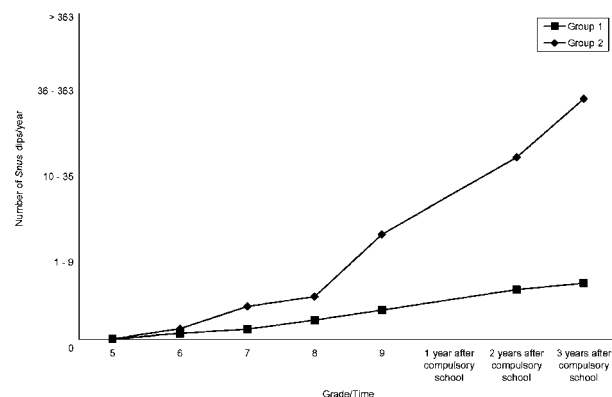


Figure 2. Trajectories of snus use among females, the BROMS Cohort Study, 1998–2005.

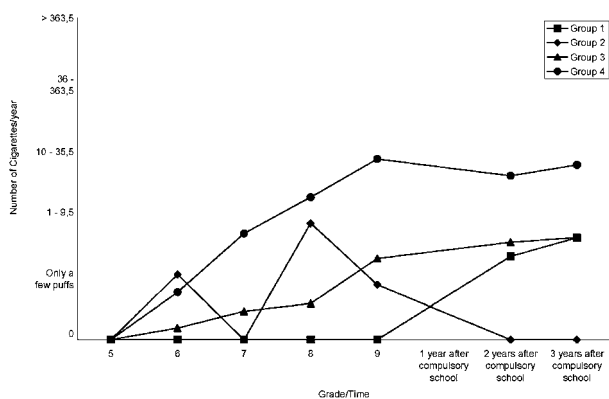


Figure 3. Trajectories of cigarette smoking among males, the BROMS Cohort Study, 1998–2005.

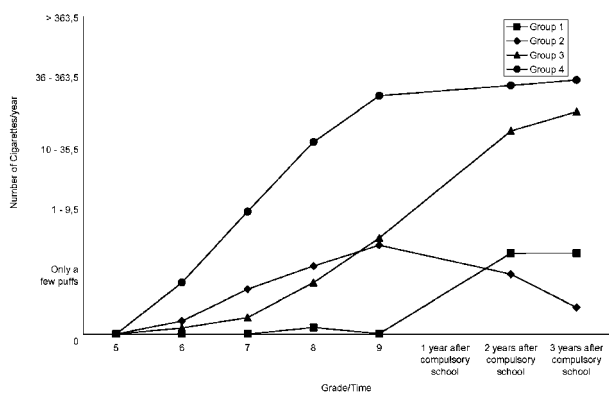


Figure 4. Trajectories of cigarette smoking among females, the BROMS Cohort Study, 1998–2005.

occurred, reaching its maximum at the end of follow-up.

3. *Early escalation*: ($n=274$, 25.1% of the males in the cohort). Median probability of group membership=95.3 (25th and 75th percentiles, 76.1 and 99.9, respectively). The development showed early onset with a rapid increase to the level of daily use by the 9th grade, leveling off thereafter.

Females' behavioral development was best described by two trajectories only, *trial* and *late escalation*, accounting for 59.7% ($n=647$) and 6.5% ($n=71$) of females, respectively. Median probability of group membership in the *trial* group was 99.4 (25th and 75th percentile, 97.3 and 99.7). Median, 25th percentile and 75th percentile of membership probability for the *late escalation* group were 84.2, 70.6 and 98.8, respectively. *Early escalation* was not observed among females. When the developmental patterns for snus use were analyzed together for the two sexes (not shown), 9.9% of all subjects were classified in the *late escalation* group and 14.3% in the *early escalation* group.

Among males (Figure 3), there were three low-consumption trajectories of cigarette smoking, of which one (*early extinction*) indicated an elevated

behavioral instability, and one (*early escalating*) peaked at weekly smoking (21.1% of males in the cohort, $n=230$). Median probability of group membership for the *escalating* group was 91.6 (25th and 75th percentile, 72.8 and 99.7, respectively).

The trajectories for cigarette smoking among females were labeled as follows (Figure 4).

1. *Late trial*: ($n=159$, 14.7% of females in the cohort). Median probability of group membership=90.1 (25th and 75th percentiles, 82.4 and 94.5, respectively). Members of this group typically started cigarette smoking around the end of the compulsory school, and were still at experimental levels of consumption 3 years later.
2. *Early extinction*: ($n=283$, 26.1% of females in the cohort). Median probability of group membership=92.9 (25th and 75th percentile, 81.0 and 98.6, respectively). In this group, early experimentation was followed by complete cessation before the end of follow-up.
3. *Late escalation*: ($n=198$, 18.3% of females in the cohort). Median probability of group membership=85.4 (25th and 75th percentiles, 63.1 and 93.2, respectively) – a pattern similar to Group 2 of snus use among males.
4. *Early escalation*: ($n=273$, 25.2% of females in the cohort). Median probability of group membership=96.3 (25th and 75th percentiles, 85.0 and 99.8, respectively) – a pattern similar to Group 3 of snus use among males.

The trajectories for cigarette smoking for the two sexes combined (not shown) closely resembled those among girls, with 14.4% of all subjects in the *late escalation* group and 16.9% in the *early escalation* group. Tables 1 and 2 show established risk factors for tobacco use as predictors of belonging to trajectories of snus use more advanced than sustained trial (reference category) and of belonging to trajectories of cigarette smoking more advanced than late trial (reference category). Being female was negatively associated to membership in advanced stages of snus use, while it was positively associated with both escalating groups of cigarette smoking. Parents' education at or above college level was not associated with advanced snus use, controlling for sex and own tobacco use, but was a negative predictor of membership in the *early escalation* group for cigarette smoking. Having at least one parent using tobacco was associated with a two-fold increase in the probability of being in the most extreme snus consumption group (Table 1). Concerning cigarette smoking, parental tobacco use was associated with both *early extinction* and *early escalation*, as did friends' tobacco use (Table 2).

In a separate analysis by sex (not shown), no predictor remained statistically significant for snus

Table 1. Predictors of membership probability in Groups 2 and 3 of snus use compared to Group 1, the BROMS Cohort Study, 1998–2005.

Group Risk factor	OR	95% CI
<i>Late escalation</i>		
Parents' tobacco use		
Neither uses tobacco	Ref	
At least one uses tobacco	1.29	0.83–2.00
Sex		
Boy	Ref	
Girl	0.26	0.17–0.44
<i>Early escalation</i>		
Parents' tobacco use		
Neither uses tobacco	Ref	
At least one uses tobacco	2.20	1.56–3.13
Sex		
Boy	Ref	
Girl	0.03	0.02–0.07

use among boys, while friends' tobacco use was the only significant predictor of the *late escalation* group of snus use among girls. In both sexes, baseline prevalence of tobacco use in a class was a significant

Table 2. Predictors of membership probability in Groups 2 and 4 of cigarette smoking compared to Group 1, the BROMS Cohort Study, 1998–2005.

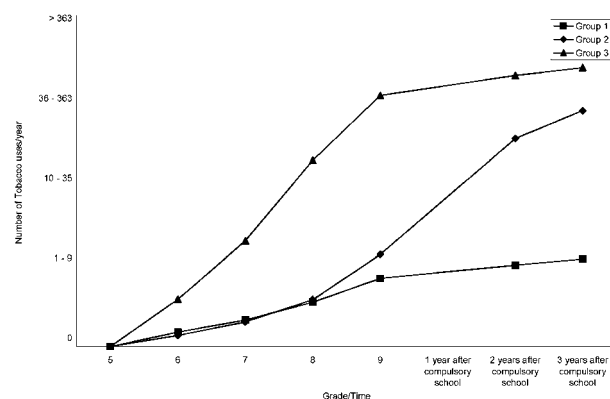
Group Risk factor	OR	95% CI
<i>Early extinction</i>		
Parents' education		
Both lower than college education	Ref	
At least one college education or above	0.79	0.57–1.08
Parents' tobacco use		
Neither uses tobacco	Ref	
At least one uses tobacco	1.47	1.06–2.02
Friends' tobacco use		
No friend uses tobacco	Ref	
At least one friend uses tobacco	2.56	1.00–6.55
Sex		
Boy	Ref	
Girl	1.04	0.76–1.43
<i>Late escalation</i>		
Parents' education		
Both lower than college education	Ref	
At least one college education or above	0.98	0.64–1.49
Parents' tobacco use		
Neither uses tobacco	Ref	
At least one uses tobacco	1.20	0.79–1.84
Friends' tobacco use		
No friend uses tobacco	Ref	
At least one friend uses tobacco	Not measurable	
Sex		
Boy	Ref	
Girl	1.65	1.08–2.51
<i>Early escalation</i>		
Parents' education		
Both lower than college education	Ref	
At least one college education or above	0.59	0.41–0.84
Parents' tobacco use		
Neither uses tobacco	Ref	
At least one uses tobacco	2.87	1.99–4.13
Friends' tobacco use		
No friend uses tobacco	Ref	
At least one friend uses tobacco	4.53	1.76–11.67
Sex		
Boy	Ref	
Girl	3.12	2.14–4.54

predictor of escalation, in addition to some of the predictors already mentioned in Table 2. When use of snus and cigarettes was analyzed in separate groups of exclusive users and dual users (both sexes combined), we obtained developmental trajectories for exclusive snus users that closely resembled those presented in Figure 2 (i.e. a *late escalation* and a *sustained trial*). We identified four developmental trajectories among exclusive cigarette smokers that closely resembled those presented in Figure 3, except that the increase in consumption for the early escalation group was not as sharp. However, the trajectories for exclusive users were based on relatively few subjects, and therefore lacked stability for further stratification by sex. Three trajectories of combined tobacco consumption best described the data of dual users (Figure 5).

There were two escalating trajectories and one trajectory indicating *sustained trial*. It should be noted that the increase in tobacco consumption among early escalating dual users was steeper than for all other escalating groups and showed no tendency to level off.

Discussion

This is the first longitudinal study comparing developmental trajectories of smokeless tobacco use and cigarette smoking throughout adolescence. In this cohort of youths, the development of smokeless tobacco (snus) use and cigarette smoking seemed to be very similar, with at least one trajectory showing early transition to heavy tobacco consumption, probably identifying a group of highly vulnerable subjects (Jamner et al., 2003). Sex-specific trajectories indicated patterns of early and steep escalation of snus use only among male adolescents, while early and steep escalation to the level of daily smoking was seen only among girls. In addition, the *heavy-consumption* trajectories in the two sexes showed

**Figure 5.** Trajectories of tobacco use among dual users (both sexes combined), the BROMS Cohort Study, 1998–2005.

very similar time progression. In other words, boys in this cohort developed heavy snus use in a similar fashion as girls did with heavy cigarette smoking. This may indicate that the transition to heavy consumption, highly correlated with nicotine dependence (Karp et al., 2005), is not a simple function of bio-behavioral factors linked to sex or of nicotine delivery system. Thus, factors explaining *early escalation* to heavy tobacco consumption in youths should be tackled in the interaction between host susceptibility and social influences to product preference (Duncan, Duncan, Biglan, & Ary, 1998). Behavioral extinction was only observed for cigarette smoking in a trajectory indicating very low intensity of use. However, groups with early increase of tobacco consumption showed a tendency to leveling-off towards the end of follow-up. This is in agreement with the notion that progression in tobacco consumption is not an indefinitely sustainable pattern during adolescence (Chassin et al., 2000). Analyses of a longer follow-up time will be necessary to eventually reveal quitting patterns in this group and in groups that were still increasing their tobacco consumption by the time they entered adulthood. Previous studies of cigarette smoking identified a higher number of developmental patterns than we found in this cohort, varying between four and six. Specifically, two studies (Chassin et al., 2000; Orlando et al., 2004) identified developmental trajectories indicating a decrease in consumption even among subjects reaching advanced stages of use—a finding that is most interesting from the point of view of public health. This difference is most likely due to the different age of the study populations. For instance, in the Chassin's (2000) study, "experimenters" and "quitters" started to decline their consumption at the age that marks the end of follow-up in our study. Unlike Orlando et al. (2004), we did not find any trajectory indicating stable high levels of cigarette smoking. Again, the most likely explanation is the younger age of our cohort at the beginning of follow-up. Colder et al. (2001), on the other end, identified a trajectory of stable light smokers and one of stable puffers, two patterns that may represent social occasional smoking and that can directly be compared to two smoking trajectories in our study labeled as *late trial* and *early extinction*. However, in our cohort this type of behavior did not seem to be stable over time, which may be partly explained by different behavioral measures. Dual users, combining snus use and cigarette smoking over time, emerged as a majority group with a high-risk profile of consumption. In fact, almost one out of five subjects in this group showed a rapid escalation trajectory with increase in tobacco consumption that was both steeper and more protracted than in any other subgroup of users. This observation adds to previous

findings from the same cohort (Galanti, Rosendahl, & Wickholm, 2008; Post et al., 2005), and from cross-sectional studies in Sweden (Galanti, Wickholm, & Gilljam, 2001), and suggests the existence of a subgroup of young tobacco users with high vulnerability to dependence and addition. We also found that known risk factors for the uptake of tobacco use, such as parents' and friends' behavior, affected in the expected direction the individual probability of transition to advanced stages of use of both snus and cigarettes. Interestingly, snus use seemed to be influenced by friends' behavior to a lower extent than cigarette smoking, and only among girls. This difference of social influences probably reflects the sex-specific background prevalence, i.e. the reinforcement from the nearest peer group may not be an important determinant of progression of snus use among males, among whom this use is widespread. Also, socio-economic differences in the prevalence of snus use and cigarette smoking in the Swedish population (Boström, 2005) can explain why the "protective" association with high parental education was only seen for cigarette smoking. In fact, at odds with cigarette smoking, snus use is not a marker of low socio-economic condition, particularly not among women. Predictors of group membership were also explored by Karp et al. (2005) with very similar results concerning the positive association of parents' and friends' use with cigarette smoking. On the other end, being a female was positively associated with a high probability of *early escalation* in our study, while the opposite was found in the study by Karp et al. (2005). Again, this difference could be explained by the fact that the smoking prevalence among Swedish youths is higher for females than for males (Hvitfeldt et al., 2005), while there is no such difference in the U.S. population (Morbidity and Mortality Weekly Report [MMWR], 2006). The major limitation of this study is inherent in its methods, in that patterns of use are not directly translated into risks at the individual level. Another concern about using model-based descriptions of behavioral development is the probability that behaviors not common enough to output a distinct trajectory are overlooked, while they may still be of great interest from the scientific and public health point of view. Therefore, when the primary interest is to follow particular subgroups of a priori interest, the model-based description may not be the best method to use. On the other hand, the model-based identification of behavioral profiles provides an alternative to subjective categorization, and enhances the comparability of findings between studies. In fact, although reasonable in some circumstances, subjective category assignment is also prone to serious pitfalls, such as over-fitting (i.e. creation of groups that reflect only random variation) (Nagin,

1999). The indirect reconstruction of the indexed behavior, as well as the 1-year time frame, are other limits of this study, considering that rapid transitions between different stages of smoking intensity are observed in adolescence (Wellman, DiFranza, Savageau, & Dussault, 2004). Also, it might be improper to generalize our findings to the whole population of the Swedish adolescents, partly because of regional differences in the use of snus (Hvitfeldt et al., 2005), and partly because some selection took place at the cohort recruitment, resulting in an over-representation of students from families with higher education (Post et al., 2003). Advantages of this study are its large size, the longitudinal design, and the detailed assessment of tobacco use across the entire span of adolescence. We conclude that tobacco prevention and treatment at young ages should not be concerned with behavioral targets based on the type of tobacco, but rather with different timelines for interventions according to common escalation patterns. Efforts should also be made to identify the subgroup of dual users with tendency to escalate to heavy tobacco use and nicotine dependence.

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