Smokeless Tobacco Use in the United States

A Compilation of Papers on Recent Research

and Discussion of Directions for

Future Research

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Initiation and Use of Smokeless Tobacco in Relation to Smoking[1]

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ABSTRACT—Questionnaire data obtained from 1,631 tenth grade students in 14 school districts in the State of Washington are used in this investigation of the relationship between the onset processes for smokeless tobacco use and smoking. Emphasized is the use of time-to-event data on the ages of occurrence of six events in these onset processes. Concepts and methods for the statistical analysis of time-to-event data are demonstrated. The occurrence of events in the smoking onset process are strongly related to increases in the subsequent onset rate for smokeless tobacco use. Compared with *before* initial smoking has occurred, the onset rates for weekly smokeless tobacco use *after* initial smoking has occurred are 2.03 ($P<.001$) and 6.72 ($P<.001$) times as large for males and females, respectively. Furthermore, both initial and weekly use of cigarettes contributes to the risk of subsequent weekly smokeless tobacco use. Conversely, the steps in the onset process of smokeless tobacco use are strongly related to increases in the subsequent smoking onset rate. Possible implications for intervention in prevention of smokeless tobacco use and for further research are discussed.—NCI Monogr 8:63-69, 1989.

The use of SLT among adolescents, especially snuff among adolescent males, has skyrocketed in recent years (*1*). This development has ominous health implications, because SLT contains known carcinogens and because a growing body of epidemiologic evidence indicates that its use carries the risk of various adverse health effects including oral cancer (*2*). Scientists are expending considerable effort to establish the circumstances and factors related to SLT use and its onset process among youth and to incorporate these findings in the designs of effective prevention programs.

Determining the relationship between smoking and the use of SLT is important for their investigation of 1) smoking as a possible risk factor for the onset of SLT use and 2) the extent to which such use is associated with subsequent smoking. That both cigarettes and SLT are tobacco products and contain absorbable nicotine indicates strongly that an associated nicotine dependence may result in individuals taking up one when quitting the other to maintain a habituated nicotine level.

It is clear that the concurrent use of cigarettes and SLT are associated (*3-6*). The purpose of our investigation is to use data on the ages at which young people begin to smoke and use SLT to examine the relationship between the smoking and SLT onset processes. Some basic concepts and methods for the statistical analysis of time-to-event data are demonstrated.

The concept of a smoking onset process, i.e., a series of events that describe an increasing level and/or frequency of cigarette use, has been advanced by Flay et al. (*7*), Leventhal and Cleary (*8*), Hirschman and co-workers (*9*), and others. Our description of such a process consists of 1) specifying meaningful events of tobacco use and 2) determining transition rates between the events with data on the times (ages) at which the events occur. The investigations reported here are restricted to such events; other important aspects of the smoking onset process, such as social influences, the environment, and motivation, will be added in subsequent investigations. We used data on the ages of occurrence of six tobacco use events: initial, tenth, and first weekly use of SLT, and initial, tenth, and first weekly use of cigarettes.

METHODS

Survey procedures.—Tobacco use, including cigarette smoking and SLT, was assessed through a questionnaire administered in the classroom to entire grades of tenth-grade students in 14 rural and suburban school districts in the State of Washington in January 1986. Through an informational letter to parents and by in-class procedures, parents and students were fully informed in advance and were given an opportunity to ask questions and to decline to participate.

The tobacco survey was part of a baseline assessment of tobacco use among students in school districts participating with the Fred Hutchinson Cancer Research Center in the Hutchinson Smoking Prevention Project, a long-term, randomized controlled trial in school-based smoking prevention.

Of the total enrollment of 2,214 tenth graders, 1,918 (87%) took part in the survey. Twelve percent were absent from class; 0.2% (parents) and 0.8% (students) declined participation. Data for all questionnaire items pertinent in this investigation are available on 1,631 students. All results reported below are based on analyses of data from 1,631 students (840 males, 791 females).

ABBREVIATION: SLT = smokeless tobacco.

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Measures we used to enhance the accuracy of the responses to the questionnaire items included 1) administration of the questionnaire on an unannounced date; 2) procedures to maintain confidentiality and assurances about these to the parents and students; 3) classroom procedures designed to maintain and demonstrate confidentiality, including the use of study identification numbers and the handling of questionnaires by project data collectors only; 4) explanation and collection of saliva samples from all participating students concurrent with administration of the questionnaire; and 5) explanation of the data collection objectives and the important role of the students in achieving them.

The questionnaire included items that assessed various aspects of current, past, and future intended use of cigarettes and SLT products. The wording for questions and multiple-choice responses for cigarettes was similar to that for SLT, so that differences in patterns for smoking and SLT use could be ascertained without confounding from differences in the nature or wording of the items.

Analysis.—For binary data items (e.g., whether a certain level of past or current use of tobacco was achieved), simple proportions (prevalences) are reported. Data on time-to-smoking and time-to-SLT-use are analyzed by standard time-to-event statistical methods (survival analysis methods) that accommodate data on individuals for which the event (smoking, SLT use) has not occurred (censoring). Two time-to-event statistical methods are used:

1) Kaplan-Meier survival curves provide a descriptive display of time-to-event data (e.g., age at initial smoking) obtained on a set of individuals. When data on time-to-event are completely available for all participants, then this curve (at any age t) is simply the fraction of individuals whose observed times-to-event are greater than t (e.g., a fraction of individuals who have not smoked at age t). The Kaplan-Meier curve can also accommodate the situation characteristic of time-to-event data, when, for some individuals, the age at initial smoking is not known, but only that no smoking has occurred by a certain age (e.g., the age at which data collection occurs). Mathews and Farewell (*10*), Lawless (*11*), Miller (*12*), and Kalbfleisch and Prentice (*13*) provide further descriptions of the Kaplan-Meier survival curve, including formulas for its computation and assumptions for its use.
2) We used the Cox regression method (*10–14*) to analyze the impact of the occurrence of one tobacco use event (e.g., initial smoking) on the subsequent rate of onset of another event (e.g., weekly use of SLT). By such analyses, one can investigate directly the interrelationship between the smoking and SLT use onset processes. The Cox regression method models the onset rate $\lambda(t)$ for some specified event (e.g., weekly use of SLT) as a function of the follow-up time t (e.g., age). The model specifies that the onset rate $\lambda(t;z)$ for any individual with explanatory (regression) variables $z_1, z_2, \ldots z_p$ is just the product of a "baseline" onset rate $\lambda_0(t)$ and a function $g(z\beta)$ of the covariates, often taken to be the exponential function $g(z\beta) = \exp(z\beta)$:

$$\lambda(t;z) = \lambda_0(t) \cdot \exp(z\beta),$$

where $\lambda_0(t) > 0$ is a completely unspecified baseline onset rate, $z = (z_1, \ldots, z_p)$ is a regression vector consisting of the p explanatory variables, and $\beta' = (\beta_1, \ldots, \beta_p)$ is a vector of regression coefficients to be estimated from the data.

The Cox regression model offers a number of desirable features and improvements over more traditional methods that make it particularly helpful in investigations of onset processes, such as those of smoking and SLT use:

1) The age-specific onset rate $\lambda(t)$, a meaningful measure of smoking onset as a function of age, is modeled directly.
2) No assumption is made about the shape or magnitude of the onset rate as a function of age. It is data determined.
3) The quantities $\exp(\beta_1), \ldots,$ for which estimates are readily obtained by the usual partial likelihood analysis, have the useful interpretation of *relative onset* rates, e.g., the estimated smoking onset rate for prior SLT users relative to that for prior nonusers.
4) As in other regression models, the effect of other variables can be conveniently controlled by their inclusion as covariates in the regression model.
5) Unlike binary data methods, the model and analysis can accommodate censored data.
6) The model can be generalized in numerous ways for adaptation to a wide range of applications.

Used in this paper is a generalization that allows an explanatory variable to depend on follow-up time t. In our application below, we let $z_1 = z_1(t)$ depend on the follow-up time (age) and define it to be the indicator function for the occurrence of a specified prior event (e.g., the occurrence of initial smoking), taking the value 0 before the event occurs and 1 afterward. The quantity $\exp(\beta_1)$ is interpreted as the relative onset rate (e.g., of weekly SLT use after the prior event of initial smoking compared with before). See the references above for a complete description of this model, its generalizations and assumptions, and method of analysis.

RESULTS

Prevalence of Smoking and Smokeless Tobacco Use

Table 1 presents, first for cigarettes and then for SLT, the fraction of boys and girls who have ever used, currently use, and have attained certain events of the onset process.

The percentage of males who have ever smoked cigarettes is about the same as have ever used SLT. More boys have dipped more than five pieces of SLT than have smoked more than five cigarettes (40.6% vs. 32.5%). Almost 70% of the females have ever smoked cigarettes and about 31% have ever used SLT; almost 6% of the girls have used more than five pieces of SLT.

More boys are currently using SLT than cigarettes: 17.7% versus 14.4% (weekly use). Although 19.4% of the girls

TABLE 1.—Current use, lifetime use, and attainment of onset events: cigarettes and SLT

	Boys, %		Girls, %	
Use/onset/transition	Cigarettes	SLT	Cigarettes	SLT
Lifetime use				
Ever	69.8	71.1	68.6	31.2
>Five times	32.5	40.6	39.1	5.9
Current use				
≥Once/mo	19.7	25.3	26.1	2.8
≥Once/wk	14.4	17.7	19.4	1.4
Onset of use				
First	69.8	71.1	68.6	31.2
Tenth	30.8	40.5	37.7	5.8
First weekly	22.4	31.1	31.2	4.4
Transition probabilities				
Between no use and first	69.8	71.1	68.6	31.2
Between first and tenth use	44.1	57.0	55.0	18.6
Between tenth and weekly use	70.3	73.6	79.9	69.8

smoke cigarettes at least weekly, only 1.4% of them use SLT at least weekly.

Consistent with the results just presented, more boys attained the tenth use for SLT than for cigarettes (40.5% vs. 30.8%), and more boys attained weekly use of SLT than cigarettes (31.1% vs. 22.4%). Also, far fewer girls attained both tenth and weekly use of SLT than for cigarettes. It is noteworthy that 4.4% of the girls did use SLT weekly at one time in their lives.

Because tobacco use onset is a process of increasing use, presentation of the results in transition probabilities (lower portion of table 1) from one event to another is helpful. These results reinforce the ideas that 1) the higher prevalence for male use of SLT compared with smoking is attributed mostly to the higher first-to-tenth use transition probability (57.0% vs. 44.1%), and 2) the drastically lower prevalence for female use of SLT compared with smoking is attributed to both a lower prevalence of initial use and a lower first-to-tenth use transition probability.

The extent to which cigarettes and SLT are used separately and concurrently is shown in table 2. Consistent with results from other studies, a strong relationship is evident between smoking and SLT use, for both lifetime and current use. First, a majority of males (60.2%) have used both cigarettes and SLT. Only about 1 of 3 males who have never tried SLT have tried cigarettes; 6 of 7 males who have tried SLT have also tried cigarettes. Fewer than 1 of 10 males who do not use SLT weekly smoke weekly, but more than 1 of 3 males who use SLT weekly also smoke weekly. Of the 25.5% of the boys who use tobacco at least once a week, 7.6% use cigarettes only, 11.7% use SLT only, and 6.2% use both.

Among females, 29.5% have used both cigarettes and SLT. Over 50% of the females who have never tried SLT use cigarettes, but more than 9 of 10 who have tried SLT have also tried cigarettes. On average, fewer than 1 in 5 girls who do not use SLT weekly smoke weekly, but more than 1 of 2 who are weekly SLT users smoke weekly.

Onset of Smoking and Smokeless Tobacco Use

The results presented to this point have described prevalence of current use, lifetime use, and the frequency of occurrence of certain onset events for smoking and SLT separately and together. These results have described the extent to which various smoking events occurred but not at what ages they occurred. Attention is now focused on the ages at which the onset events occurred, with emphasis on a description of the age-specific onset rates for first, tenth, and first weekly use for smoking and SLT. First, smoking and

TABLE 2.—Relationship between smoking and SLT use, %

Sex	Use/onset	Cigarettes only	SLT only	Cigarettes and SLT	Neither
Males	Lifetime use				
	Ever	9.5	10.8	60.2	19.4
	>Five times	10.2	18.4	22.3	49.3
	Current use				
	≥Once/mo	7.8	14.6	11.1	66.5
	≥Once/wk	7.6	11.7	6.2	74.5
	Onset of use				
	First	9.6	10.7	60.5	19.2
	Tenth	9.4	19.0	21.4	50.1
	First weekly	9.0	17.7	13.3	59.9
Females	Lifetime use				
	Ever	39.1	1.6	29.6	29.7
	>Five times	33.7	0.6	5.3	60.4
	Current use				
	≥Once/mo	24.0	0.8	2.0	73.3
	≥Once/wk	18.5	0.8	0.7	80.1
	Onset events of use				
	First	38.9	1.6	29.8	29.6
	Tenth	32.4	0.5	5.3	61.8
	First weekly	27.7	0.9	3.5	67.9

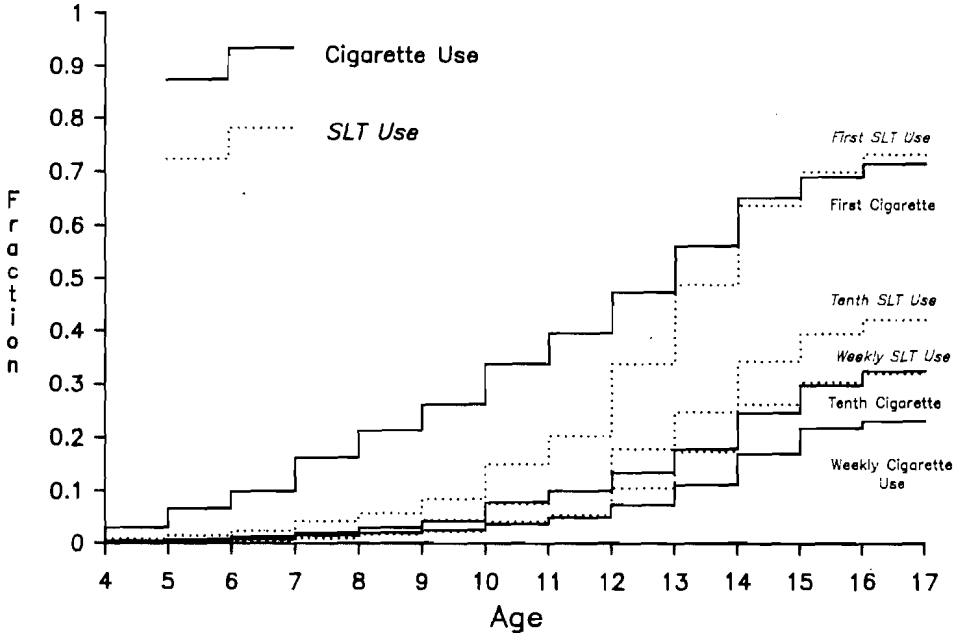

FIGURE 1.—Onset curves for smoking and SLT for 840 adolescent males.

SLT are considered separately and then together. We used basic methods of presenting and analyzing time-to-event data. The onset curves for first, tenth, and weekly use for cigarettes and SLT are shown in figures 1 and 2 for males and females, respectively. The onset curves indicate that the rates are greatest (onset curves increase the fastest) during certain age ranges shown in table 3.

It is clear that substantial differences exist between the age ranges when smoking and SLT onset occur. For males and females, initial SLT use occurred later than initial smoking. For males, tenth and weekly SLT use did not occur later than tenth and weekly use of cigarettes. Rather, the onset rates were similar until the boys were 11 years old, after which more boys achieved tenth and weekly SLT use than tenth and weekly smoking. For females, tenth and weekly SLT use occurred later than tenth and weekly use of cigarettes.

Relationship Between Smoking Onset and Onset of Smokeless Tobacco Use

The relationship between the onset of smoking and that of SLT use in adolescents was investigated by a number of methods.

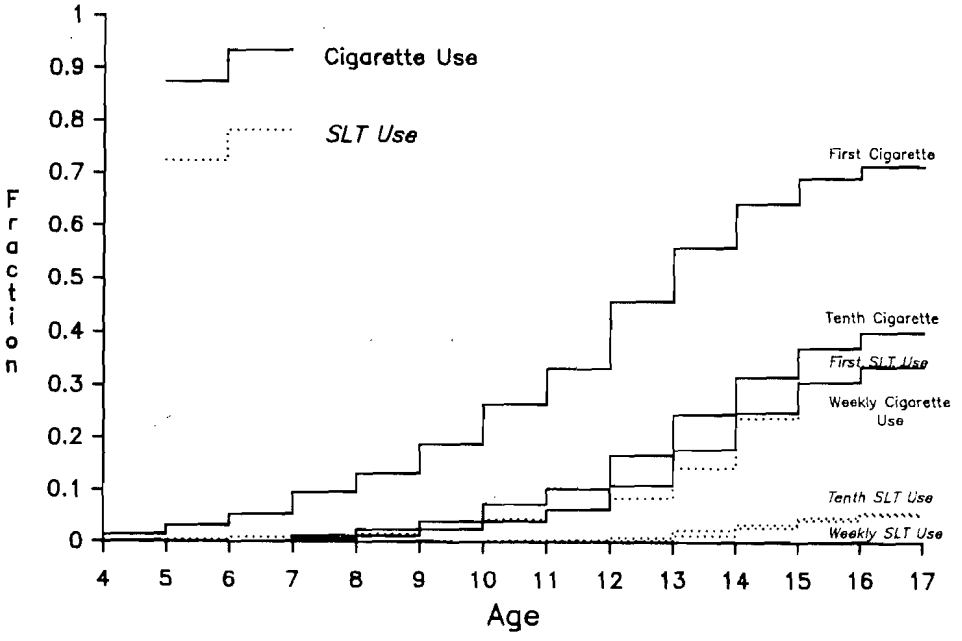

FIGURE 2.—Onset curves for smoking and SLT for 791 adolescent females.

TABLE 3.—Age ranges for high onset rates

Sex	Use: First — Age range, yr	First — Percent onset[a]	Tenth — Age range, yr	Tenth — Percent onset[a]	First regular — Age range, yr	First regular — Percent onset[a]
Males						
Smoking	6-14	55	9-15	26	11-15	14
SLT	9-14	55	11-15	30	11-15	25
Females						
Smoking	8-14	51	9-15	33	10-15	27
SLT	12-16	26	11-15	5	12-16	5

[a] Percent onset is for age range indicated.

First, joint distributions were computed for the age of occurrence of an event in the smoking onset process and that of the corresponding event in the SLT onset process. Time-to-event censoring was handled by inclusion of a "never started" category. From the joint distributions (not shown) of: 1) age at first use of cigarettes and at first use of SLT, 2) age at tenth use of cigarettes and age at tenth use of SLT, and 3) age at regular use of cigarettes and at regular use of SLT, a number of conclusions can be obtained.

One summary point of the joint distribution of ages of initiation of smoking and SLT use is the extent to which the smoking event occurs before the SLT use event, and vice versa, among those experiencing both smoking and SLT use events. As shown in table 4, smoking and SLT each occurred first in a substantial number of males. Among boys who used both, 25% tried SLT first and 60% tried cigarettes first. Fifteen percent first tried both at the same age. In contrast, the vast majority of females tried cigarettes first (76%) rather than SLT first (12.5%).

Finally, the following question is addressed: How are the age-specific onset rates for regular smoking related to the prior occurrence of steps in the SLT onset process for the 840 boys and 791 girls? Conversely, how are the onset rates for regular SLT use related to the prior occurrence of steps in the smoking onset process for both sexes? We investigated these questions using time-to-event regression methods developed by Cox (*14*). Data for all participants are included in these analyses; those not experiencing the end point of interest (e.g., weekly smoking, in table 5) are treated as censored.

The occurrences of steps in the SLT onset process are strongly related to increases in subsequent onset rate for weekly smoking. From runs (i.e., individual analyses) 1 and 4 of table 5, the weekly smoking onset rate is 1.65 ($P = .002$) and 2.13 ($P < .001$) times as large for males and females, respectively, after initial SLT use has occurred compared with before initial SLT use. From runs 2 and 5, the weekly smoking onset rate is 1.83 ($P = .002$) and 3.25 ($P = .021$) times as large for males and females, respectively, after weekly SLT use began compared with before weekly SLT use.

Furthermore, evidence suggests that *each* of the SLT steps, initial and weekly use, contributes to the risk of subsequent weekly smoking. When both steps are included in the analyses for males (run 3), the occurrence of initial SLT multiplies the risk of smoking onset by 1.45 ($P = .047$), and the subsequent occurrence of weekly SLT use multiplies the risk of smoking onset by an additional 1.47 ($P = .08$) for a net multiple (1.47×1.45) of 2.13 times the smoking onset rate when no SLT event has occurred. For females (run 6), the relative risks are 2.04 ($P < .001$) and 1.80 ($P = .27$); not enough females use SLT regularly to provide the data needed in this data set for us to determine whether weekly SLT use provides an added risk of weekly smoking beyond the risk provided by initial SLT use.

The results for the converse relationship are similar (table 6). The occurrences of steps in the smoking onset process are strongly related to increases in the subsequent onset rate for SLT use. From runs 1 and 4 of table 6, the onset rate

TABLE 4.—Precedence of smoking vs. SLT among individuals using both, %

Use	Smoking event occurred first	SLT use occurred first	Simultaneous occurrence
Males			
First	60.0	24.9	15.1
Tenth	44.2	28.2	27.6
Weekly	43.4	31.0	25.6
Females			
First	76.3	12.5	11.2
Tenth	73.8	11.9	14.3
Weekly	60.7	14.3	25.0

TABLE 5.—Results of relative risk regression analyses of relationship of steps in onset process of SLT with onset of weekly smoking[a]

Run	Relative rate and 95% confidence interval of weekly smoking onset[b]: After initial SLT use	P	After weekly SLT use	P
Males				
1	1.65 (1.20, 2.29)	.002	—	
2	—		1.83 (1.24, 2.69)	.002
3	1.45 (1.00, 2.09)	.047	1.47 (0.95, 2.27)	.08
Females				
4	2.13 (1.50, 3.02)	<.001	—	
5	—		3.25 (1.20, 8.81)	.021
6	2.04 (1.42, 2.93)	<.001	1.80 (0.64, 5.07)	.27

[a] Analyses used data on 840 males and 791 females, of whom 188 and 247, respectively, attained weekly smoking.

[b] *Values in parentheses* represent 95% confidence intervals.

TABLE 6.—Relative risk regression analyses of relationship of steps in onset process of smoking with onset of weekly SLT use[a]

Run	Relative rate and 95% confidence interval of weekly SLT use[b]			
	After initial smoking	P	After weekly smoking	P
Males				
1	2.03 (1.56, 2.62)	<.001	—	
2	—		3.50 (2.55, 4.82)	<.001
3	1.65 (1.25, 2.18)	<.001	2.74 (1.95, 3.85)	<.001
Females				
4	6.72 (2.34, 11.92)	<.001	—	
5	—		4.57 (2.31, 9.06)	<.001
6	4.56 (1.49, 14.0)	<.001	2.63 (1.29, 5.40)	<.001

[a] Analyses used data on 840 boys and 261 events and 791 girls with 35 events.

[b] *See* table 5, footnote *b*.

for weekly SLT use is 2.03 ($P < .001$) and 6.72 ($P < .001$) times as large for males and females, respectively, after initial smoking has occurred than that before it occurred. This result for females is particularly striking: Females who have tried cigarettes are at almost seven times the risk for using SLT as those who have not. From runs 2 and 5, the onset rate for weekly SLT use is 3.50 ($P < .001$) and 4.57 ($P < .001$) times as large for males and females, respectively, after weekly smoking than before it occurred. Furthermore, evidence is clear that *each* of the smoking onset steps, initial and weekly use, contributes to the risk of subsequent weekly SLT use. When both steps are included in the analysis for males (run 3), the occurrence of initial smoking multiplies the risk of onset of weekly SLT use by 1.65 ($P < .001$), and the (subsequent) occurrence of weekly smoking multiplies the risk of onset of weekly SLT use by an additional 2.74 ($P < .001$), for a net multiple (1.65×2.74) of 4.5 times the SLT onset rate when no smoking event has occurred. The corresponding multiples for females (run 6) are 4.56 ($P < .001$), 2.631 ($P < .001$), and 12.0 (4.56×2.63).

DISCUSSION AND CONCLUSION

A consistently strong relationship is observed between the onset processes of SLT and smoking among adolescents. In particular, the occurrence of events in the smoking onset process is strongly related to increases in the subsequent onset rate for SLT use. Conversely, the occurrence of steps in the onset process of SLT use is strongly related to increases in the onset rate of subsequent smoking.

The finding that prior use of SLT is a risk factor for smoking indicates that prevention of its use may also help prevent smoking. Conversely, the finding that prior smoking is a risk factor for SLT use indicates that prevention of smoking may also help prevent SLT use. These results indicate the possible desirability of combining the prevention components of both within an overall intervention program. Such integration also makes practical sense in light of the tobacco common denominator between smoking and SLT use and the needs of schools for integrated interventions.

Several limitations of this investigation should be noted. The data used in these analyses on the onset processes for smoking and SLT use are recall data collected retrospectively from a cross-sectional survey. Resulting limitations include: 1) Recall bias may be present because the data are limited to those individuals who can remember, and the recall may be biased among those who remember. 2) The sample does not correspond to a defined cohort but is a modification (by in- and out-migration) of some identifiable original cohort. However, to the extent that in- and out-migrating students are similar in their SLT and smoking onset patterns, no bias would result.

Also, these data on occurrence of events in the smoking and SLT onset processes span a period (1975–1985) during which the prevalence of SLT use was increasing rapidly. As a result, the relationship between the onset of both during such a period necessarily includes the effects of temporal changes in prevalence.

These investigations illustrate how survival analysis methods, and in particular survival analysis regression methods, can help to provide insight into the onset of individual steps of the smoking onset process, the relationship between age and the onset rate of various tobacco use events, and the degree to which onset of different events are related. Results of such investigations can contribute to the design of health-promoting interventions by guiding the choice of component, delivery method, and age and grade at which they are provided.

Further research is indicated in several directions: how the effect of SLT use on subsequent smoking onset depends on age and inclusion of other aspects of the tobacco use onset processes including social, environmental, and motivation variables. Finally, cohort studies are needed.

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