Most smokeless tobacco use is not a causal gateway to cigarettes: using order of product use to evaluate causation in a national US sample

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Submitted 10 September 2002;
initial review completed 27 January 2003;
final version accepted 10 February 2003

ABSTRACT

Aims To evaluate non-causal and causal patterns of smokeless tobacco (SLT) and cigarette use; to assess the prevalence of 'non-gateway' and possible 'gateway' patterns of SLT use.

Design and setting Data from the Cancer Control Supplement to the 1987 National Health Interview Survey, a representative survey of non-institutionalized adults in the United States. From reported age at first use, participants were categorized by type and sequence of tobacco product use. SUDAAN 8.0.1 was used for statistical analyses.

Participants Males aged 18–34 ($n = 3454$), weighted to provide estimates of the US population. A subsample of males aged 23–34 ($n = 2614$) was analyzed to minimize the possibility of future product switching.

Measurements Smoking status, smokeless tobacco (snuff, chewing tobacco, both) use status, age at regular use of cigarettes, age at first use of smokeless tobacco.

Findings Of those 23–34-year-olds who had ever used SLT with or without cigarettes, 77.2% (95% CI: 71.3, 83.3) were classifiable as non-gateway users in that 35.0% (95% CI: 29.9, 40.1) had only used SLT and 42.2% (95% CI: 36.8, 47.7) had used cigarettes first. Cigarette use in younger cohorts was less common, despite increased SLT use. Those who used cigarettes before moist snuff were 2.1 times more likely to have quit smoking (95% CI 1.21,6.39) than cigarette-only users.

Conclusions The large majority of SLT users are non-gateway users. Causal gateway effects should be of minor concern for policy. SLT may be more likely to prevent smoking than cause it.

KEYWORDS Gateway, risk factors, smoking, smokeless tobacco.

INTRODUCTION

Much contemporary policy on smokeless tobacco (SLT) in the United States and Europe is influenced by concern that smokeless tobacco acts as a causal 'gateway' to a more unhealthy nicotine-delivery system: cigarettes (e.g. McNeill 1990; Nordgren & Ramström 1990; National Cancer Institute 1992; Ferrence *et al.* 2001; Haddock *et al.* 2001; Stratton *et al.* 2001; Tomar 2002, 2003). The causal gateway argument holds that prior use of SLT causes an increased probability of subsequent use of cigarettes. For SLT to be judged a causal gateway to cigarette smoking in any individual, it is important to know which product was used first. This simple priority principle (e.g. Davis 1985), so critical in establishing that cigarette smoking causes disease (USDHEW 1964), has sometimes been neglected in research on SLT as a causal gateway to cigarettes.

Several authors have pointed out deficiencies of causal gateway models (e.g. Baumrind 1983; Kandel & Jessor

2002). A detailed review (Kandel & Jessor 2002, p. 366) has found: 'There is no compelling evidence that the use of a drug earlier in the sequence, *in and of itself* [emphasis added] causes the use of any other drug'. Nevertheless, the causal gateway hypothesis remains prominent in ostensibly science-based policy (of course, the SLT/cigarette gateway is special in that it does not involve transitions to different types of drugs, but rather transitions between two forms of one drug: nicotine). A correlation between SLT use and smoking is not adequate to establish a causal link. Some of the correlation among the use of drugs of abuse is due to the association of non-use as well as use (Miller 1994). In other words, people who are very unlikely to ever try drug 'A' can also be very unlikely to ever try any other drug of abuse (Kozlowski & Harford 1976; Miller 1994). With the diminishment of the issue that some smokeless products (Swedish snus) cause cancer (Lewin *et al.* 1998; see also Accortt *et al.* 2002), the causal gateway issue has become even more influential in guiding tobacco and harm-reduction policy.

Although some experts apply the gateway model in only a non-causal, associative sense (see Kandel & Jessor 2002), our evaluation is directed to the causal gateway model, because this causal model has clearer implications for policy (i.e. promoting SLT use for harm reduction could cause an increase in smoking; or stopping SLT use could act to stop cigarette smoking). The causal gateway argument holds that prior use of SLT increases the probability of subsequent use of cigarettes. This argument does not require one to think that cigarette smoking occurs if and only if there has been prior use of SLT, but that some smoking would not have occurred if not for prior use of SLT.

Prior evidence supporting a dominant causal SLT gateway effects is weak

Prior to 1999, there were several longitudinal studies in the United States on SLT as a possible causal gateway to cigarettes. The review published in the 1994 US Surgeon General's Report (USDHHS 1994) describes the results as mixed, with some studies showing that SLT use predicted smoking (e.g. Peterson *et al.* 1989) and others showing that smoking predicted SLT use (e.g. Murray *et al.* 1988). Among recent studies, Griffin *et al.* (1999) and Hatsukami *et al.* (1999) found no association between SLT use and later cigarette smoking, while Cohen-Smith & Severson (1999) found that smoking predicted later SLT use.

Recent attention has focused on two large longitudinal studies. Haddock *et al.* (2001) studied military recruits who were non-smokers at the beginning of basic training and evaluated whether SLT use predicted subsequent smoking. Past and current SLT users (at baseline) were each about 2.3 times more likely to have begun smoking at follow-up (Haddock *et al.* 2001). This study is limited in two major ways. First, male military recruits (who have not started smoking by age 18) are probably unrepresentative of males in the general population. Secondly, their definition of smoking changed from baseline to follow-up. At baseline, smokers were defined as having smoked at least one cigarette per day (time-frame is not specified, but we assume the past 7 days, consistent with their other definitions), while at follow-up smoking was defined as having a single puff on a cigarette in the preceding seven days. Tomar (2003) used the longitudinal component of Teenage Attitudes and Practices Survey to evaluate progression to smoking 4 years later in 12–18-year-olds who were never smokers at time 1. His analyses found that SLT use at time 1 predicted onset of smoking by time 2. However, two major limitations of this study were that (1) the never smokers at time 1, especially for older adolescents, comprise a complexly biased sample, and (2) available psychosocial predictor variables were not included in the model. Longitudinal studies (Haddock *et al.* 2001; Tomar 2003) do have advantages over cross-sectional studies, but they do not necessarily provide adequate analyses of causal effects. They remain fundamentally correlational, not experimental studies.

Tomar has also analyzed cross-sectional adult data from the 1998 National Health Interview Survey in the United States (Tomar 2002), but this survey did not ask about age at first use of smokeless products, so no analyses were possible on sequence of product use. He reported that males were 2.5 times more likely to be former snuff users who currently smoked than to be former smokers who currently used snuff (2.5% versus 1%). He proposed that SLT 'may be a "gateway" form of nicotine dosing…that may lead to subsequent smoking' (Tomar 2002, p. 147), phrasing that implies a causal function, especially in a paper that discusses harm reduction themes.

Our approach

There is a fundamental asymmetry in causal analysis that employs the order of first use of SLT and cigarettes. If cigarette use follows SLT use it is possible, but not certain that SLT use has caused smoking in some individuals. On the other hand, for SLT users who have used SLT but never go on to cigarettes, it is certain that SLT has not caused smoking in any of these individuals (provided one uses old enough samples, such that recruitment to smoking is over). Similarly, for those who first smoked cigarettes, it is illogical to think that SLT use caused smoking in these individuals. Together the two categories of sole SLT use and prior cigarette use constitute a broad class of SLT users for whom SLT use is not a causal gateway to

cigarettes. Estimating the prevalence of such non-gateway uses of SLT provides a way to estimate an upper limit on how large a public health problem a causal SLT gateway might be. In other words, if one-third of SLT users might be victims of a causal gateway, one can be confident that at least 67% of SLT users are not examples of a causal gateway. Also, unless one makes the unreasonable assumption that 100% of prior SLT users have had their smoking caused by SLT use (i.e. they would not have smoked otherwise), one should view that, logically, 'non-gateway' users provide a conservative estimate of the overall non-gateway patterns of use. This analytical framework is different from the more traditional scheme of estimating if use of SLT is more associated with smoking than is non-use of SLT, because it arises from a special, logic-based analysis of what interpretations are sensible from specific patterns of use.

Ramström (1990, 2001) has reported data on 18–34-year-old males from a survey in Sweden (1987–88) that asked a direct question on whether cigarettes or SLT were used first. SLT in this study was Swedish snus, a low nitrosamine, oral moist snuff that is placed in the upper front of the mouth between the lip and gums. He found substantial numbers of respondents who used snus solely or after they started smoking cigarettes, but he did not put forward the same logical analysis of the interpretations arising from the different patterns of use.

The National Health Interview Survey, 1987 (UHDHHS 1987) asked about age of using cigarettes, snuff and chewing tobacco. By comparing age at use of these products, we tried to replicate the patterns found in Sweden and to evaluate what can be learned from a consideration of priority of use, under the assumption that sole users of SLT and prior users of cigarettes are 'non-gateway' users and prior users of SLT who went on to cigarettes should be considered 'possible gateway' users.

METHODS

Data

Data for this study were obtained from the Cancer Control Supplement to the 1987 National Health Interview Survey (NHIS) (USDHSS 1988), a representative survey of non-institutionalized adults in the United States. The NHIS is a continuous, nation-wide, household survey of the civilian population. In 1987, 22 043 individuals completed the Cancer Control supplement (a response rate of 86%) (Schoenborn & Boyd 1989). Public use data are available on CD-ROM from the National Center of Health Statistics. Complete details about the complex survey design and procedures are available elsewhere (see Schoenborn & Boyd 1989; Appendix I).

Subjects

We limited our sample initially to males aged 18–34 to provide an exact replication of Ramström (1990, 2001); this provided a sample size of 3454. At a second stage, to be conservative in estimating those who were users of smokeless tobacco only (i.e. those who never use cigarettes), we limited the sample to 23–34-year-olds ($n = 2614$). We selected the age of 23 as the lower cut-off, because no one in this sample who first used snuff and then used cigarettes regularly had started smoking after age 22. This provided a category of SLT only users who would be very unlikely to include those who might still recruit to smoking. Note that sample sizes reported in tables will be smaller due to missing data.

Creating tobacco use categories

Figure 1 depicts the process for determining six tobacco use categories using a series of questions from the survey. The final six categories are SLT only, cigarettes first, SLT first, same time, cigarettes only and never users of tobacco. In order to reach the final six categories, we first determined life-time tobacco product use for cigarettes, snuff, chewing tobacco and combined snuff and chewing tobacco use (referred to as combined SLT use) followed by an analysis of order of tobacco product use. Life-time cigarette use was determined by asking whether 100 cigarettes had been smoked. Participants were categorized as never (smoked 0–99 cigarettes) or ever (100 or more cigarettes) smokers. Life-time snuff use was assessed by asking whether snuff had been used 20 times. Participants were characterized as never (used 0–19 times) or ever (used 20 or more times) snuff users. Analyses of snuff use were limited to moist snuff users, removing individuals who reported any dry snuff use. This was employed because of the very small number of dry snuff users (10), potential differences between dry

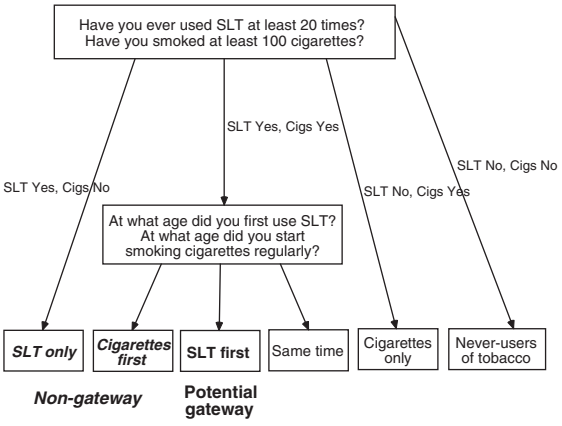

Figure 1 Derivation of tobacco use categories, NHIS 1987

and moist snuff users and because moist snuff is the US product most comparable to Swedish snus. A similar scheme was used to assess chewing tobacco use. Finally, a combined smokeless tobacco (SLT) use variable was created, combining those who had used moist snuff, chew or both into a single variable. Participants were characterized as never (used neither snuff nor chew) or ever (used snuff, chew, or both). Ever users of snuff, chew, SLT and cigarettes were further divided into former (no use in past 30 days) and current users (used at least once in past 30 days).

Those who could be classified as 'never' for cigarettes, snuff and chewing tobacco were called 'never users'. Those who reported snuff and/or chewing tobacco use but no cigarette use formed a second category (SLT only). Similarly, those who reported cigarette use but no snuff and/or chewing tobacco use formed a third category (cigarette only).

Order of tobacco product use was determined as follows. For those participants who could be classed as ever for cigarettes and SLT, the age at which they started using cigarettes regularly, and the age at which they first used snuff/chewing tobacco was next considered. These different questions were used because parallel age questions for cigarettes and smokeless were not asked. For the combined SLT variable, age at first use was determined by the lower age of the two SLT products (for those with combined use) or by the age at first use of whichever SLT product was used (for those who used only one product). To determine which tobacco use came first, age at first snuff use, age at first chewing tobacco use and age at first SLT use were each subtracted from age at regular cigarette smoking. If age at regular cigarette smoking was less than age at first snuff use, then cigarettes were judged to have been used first (cigarettes first). Similarly, if age at first snuff use was less than age at first cigarette use, then snuff was judged to have come first (snuff first). Some participants reported using both cigarettes and SLT at the same age—hence a separate category was created for those with no age difference (same time).

We believe that our classification method provides an upper-bound estimate of gateway effects, as the snuff first group is probably overestimated (because age at regular snuff use is not available) and the cigarettes first group probably underestimated (because age at regular use, rather than first use is employed). Three different smokeless tobacco use classifications were used: snuff, chewing tobacco, and combined SLT. For the snuff and chewing tobacco variables, users of the other smokeless products were not excluded. Hence, someone categorized as 'snuff only' may have also used chewing tobacco, but did not smoke. Someone who is designated 'neither' did not use snuff or cigarettes, but may have used chew.

Analyses

Descriptive statistics on tobacco use categories were computed with SUDAAN 8.0.1 (Research Triangle Institute 2002) in order to accommodate the complex NHIS sample design. Statistical inferences were performed through the use of 95% confidence intervals (CI) around percentages (see Altman *et al*. 2000). If CIs overlapped, then two groups were not significantly different at the alpha = 0.05 level; if CIs did not overlap, then the groups were different at the alpha less than 0.05 level. We also compared our computed values to those reported by Ramström (1990, 2000), again using 95% CIs to assess significant differences. A χ^2 test was used to test for significant differences in the distribution of tobacco use categories by age cohort. All logistic regression models were non-sequential and controlled for age, education and region of the United States (North-east, North-central, South, West). Odds ratios and confidence intervals were used to indicate effect sizes and statistical significance.

RESULTS

Results are arranged as follows. First, a replication of the Ramström (1990) study is presented using the 18–34-year-old sample. Secondly, the sample is narrowed to those aged 23–34. Thirdly, we divide the sample into three age cohorts and reanalyze patterns of tobacco use. Fourthly, analyses similar to previous evaluations of gateway effects are presented, along with the consequences of considering order of use. Finally, we present analyses of smoking cessation behavior in mixed cigarette–SLT users and exclusive cigarette users, by order of use.

Comparing patterns of non-gateway and possible gateway snuff use in Sweden and the United States around 1987

Moist snuff is the product in the United States most similar to Swedish snuff (snus). Table 1 shows the pattern of snuff use and smoking in six mutually exclusive categories for the United States and five mutually exclusive categories for Sweden for males aged 18–34. Levels of snuff use were much higher in Sweden than the United States (all *P*s < 0.05). The Swedish values come from Ramström (1990). Figure 2 shows non-gateway and possible gateway use as a percentage of ever use of SLT. Patterns of use for those who had ever used snuff with or without cigarettes were very similar. The large majority of snuff users in Sweden (83%) and the United States (77.2%) appear to be 'non-gateway users', in that their snuff use did not lead to smoking or their smoking preceded snuff use. Only 17.5% of Swedish users and 22.9% of US users used SLT

Table 1 Prevalence of ever use of moist snuff[a] and cigarettes as a function of order of product use, solitary product use, and never use in US males aged 18–34, NHIS 1987 and Swedish males 18–34, 1986–1987.

	Tobacco use status						
	Non-gateway		*Potential gateway*				
	Snuff only	*Cigarettes first*	*Snuff first*	*Snuff and cigarettes in same year*	*Cigarettes only*	*Neither snuff nor cigarettes*	*Total*
Sweden							
% Ever use	18	15	7		21	39	100
(95% CI)	(16.7,19.3)	(13.8,16.2)	(6.1,7.9)	N/A	(19.6,22.4)	(37.3,40.7)	(*n* = 824)
United States							
% Ever use	4.3	3.1	2.2	0.5	39.7	50.1	100
(95% CI)	(3.6,5.0)	(2.4,3.8)	(1.7,2.7)	(0.23,0.77)	(37.7,41.7)	(49.0,52.2)	(*n* = 3297)

[a]In Sweden, moist snuff is *snus*.

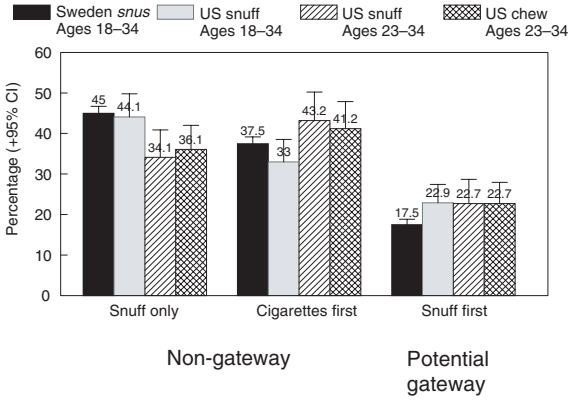

Figure 2 Distribution of non-gateway and potential gateway users of smokeless tobacco, Sweden 1987–88 and US NHIS 1987. US snuff data plotted for both 18–34 cohort and 23–34 cohort. Chewing tobacco data plotted for 23–34 cohort only. Error bars show 95% CI

before smoking and therefore are possibly gateway users, a small difference in percentage points, but statistically significant ($P < 0.05$).

Patterns of non-gateway and possible gateway tobacco use in US males aged 23–34

The remaining analyses do not include those aged 18–22. Individuals in this excluded group still carry significant risk of becoming cigarette smokers. By limiting the sample to those 23 or older, we have much greater confidence that very few, if any, of those in the SLT only group might still become members of the SLT first group. On average, SLT was used 4.0 years (SEM = 0.30) before cigarettes by those who had used SLT before cigarettes; cigarettes were used 5.6 (SEM = 0.38) years before SLT by those who used cigarettes first. These numbers indicate that there was, on average, a substantial time lag from using one product to switching products or adding another.

Table 2 shows the patterns of snuff, chew and combined SLT use as a function of the six mutually exclusive categories of use among US males aged 23–34. Only a small percentage of users (less than 1%) started using both products in the same year. Figure 2 shows the non-gateway and possible gateway use as a percentage of all those who had ever used snuff or chew. (The same values can be calculated from Table 2 for SLT.)

Cohort effects

To investigate age-related patterns of tobacco use, we cross-tabulated age (categorized as 23–26, 27–30 and 31–34) with tobacco use category (see Table 3). χ^2 analysis showed significant differences in the distribution of tobacco use by age [$\chi^2(10) = 46.79$, $P < 0.0001$]. While 'cigarettes only' use was 9.3% lower in the youngest age group than the oldest group, 'SLT only' use was 5.1% higher. Use of SLT before cigarettes was 1.7% higher in the youngest group than the oldest group, while Cigarettes-before-SLT use was 2.4% lower.

Combining values in Table 3, we find that ever smoking (middle four categories of Table 3) was 10.3% lower in the youngest age group [46.6% (95% CI: 42.5,50.7) versus 57.0% (95% CI: 53.3,60.7)] compared to the oldest group [$\chi^2(2) = 16.2$, $P = 0.0007$]. Ever SLT use (first four categories) was 4.1% higher [17.0% (95% CI: 14.1,19.9) versus 12.9% (95% CI: 10.4,15.4)] over the same comparison [$\chi^2(2) = 4.9$, $P = 0.096$]. That is, there were 32% more ever SLT users among the youngest group compared to the oldest group, while ever smoking decreased by 18%. Logistic regression showed that the youngest age

Table 2 Prevalence of ever use of smokeless tobacco (moist snuff, chewing tobacco, and combined smokeless) and cigarettes as a function of order of tobacco product use, single tobacco product use and never use in males aged 23–34, NHIS 1987. Percentages are weighted to the US population.

	Tobacco use status						
	Non-gateway		*Potential gateway*				
	SLT product only	*Cigarettes first*	*SLT product first*	*SLT product and cigarettes in same year*	*Cigarettes only*	*Neither SLT product nor cigarettes*	*Total*
Moist snuff							
%	3.0	3.8	1.9	0.5	44.9	45.9	100
(95% CI)	(2.3,3.7)	(2.9,4.7)	(1.3,2.5)	(0.2,0.8)	(42.6,47.2)	(43.5,48.3)	(*n* = 2498)
Chewing tobacco							
%	3.6	4.1	2.2	0.6	44.1	45.5	100
(95% CI)	(2.9,4.3)	(3.3,4.9)	(1.6,2.8)	(0.3,0.9)	(41.7,46.5)	(43.2,47.8)	(*n* = 2497)
Combined SLT							
%	5.0	6.0	3.2	0.7	41.0	44.0	100
(95% CI)	(4.2,5.8)	(4.9, 7.1)	(2.5,3.9)	(0.4,1.1)	(38.6,43.4)	(41.7,46.3)	(*n* = 2492)

Table 3 Distribution of tobacco product use categories as a function order of using these products, sole use and never use, males aged 23–34, by 4-year age cohort, NHIS 1987. Percentages are weighted to the US population.

	Tobacco use status						
	Non-gateway		*Potential gateway*				
	SLT product only	*Cigarettes first*	*SLT product first*	*SLT product and cigarettes in same year*	*Cigarettes only*	*Neither SLT product nor cigarettes*	*Total*
23–26							
%	8.0	4.4	4.0	0.57	37.7	45.4	100
(95% CI)	(6.0,10.0)	(2.9,5.9)	(2.6,5.4)	(0.0,1.1)	(33.7,41.7)	(41.1,49.7)	(*n* = 801)
27–30							
%	4.0	6.8	3.4	0.75	38.6	46.5	100
(95% CI)	(2.6,5.4)	(4.8,8.8)	(2.0,4.8)	(0.10,1.4)	(34.9,42.3)	(42.8,50.2)	(*n* = 852)
31–34							
%	2.9	6.8	2.3	0.88	47.0	40.1	100
(95% CI)	(1.8,4.0)	(5.1,8.5)	(1.3,3.3)	(0.21,1.6)	(43.1,50.9)	(36.4,43.8)	(*n* = 839)

group was 0.58 times as likely to be ever smokers (versus never smokers) (95% CI: 0.46,0.74) as the oldest age group. At the same time, the youngest age group was 1.4 times more likely to be an ever SLT user (versus never SLT users) (95% CI: 1.01,1.84). This pattern of results does not indicate that increased use of SLT was associated with increased smoking; on the contrary, it shows a negative relationship between SLT and cigarette use.

Analyses using more traditional methods to evaluate gateway effects

As others have reported, we found a positive relationship between SLT use and cigarette smoking when use of both was dichotomized as ever/never [$\chi^2(1) = 40.8$, $P < 0.0001$; relative risk = 1.4 (95% CI: 1.3,1.5); $\phi = 0.13$]. When smoking and SLT were designated as Non, former, current, we find that there were more current smokers who were former SLT users [4.5% (95% CI: 3.5,5.5) of the sample] than there were current SLT users who were former smokers [1.4% (95% CI: 0.8,2.0) of the sample] (see Tomar 2002). In a logistic regression model, ever-use of SLT was a significant predictor of current smoking (OR = 1.35, 95% CI: 1.05, 1.74). However, if we remove those who used cigarettes before they used SLT (i.e. those in whom SLT could not logically have caused smoking, but could contribute to an association), the results change. Ever-use of SLT is no longer a significant

predictor of current smoking (OR = 0.79; 95% CI: 0.56, 1.11). These results argue strongly for consideration of order of use.

Quitting smoking

Ramström (2000) reports increased smoking cessation in ever snus users who first used cigarettes. We also looked at quitting behavior of smokers by snuff use category. Multiple logistic regression showed that those who used cigarettes before snuff were 2.1 times more likely to have quit smoking (95% C.I. 1.21,3.45) than were cigarette-only users. No significant effect on quitting was seen for those who used snuff first compared to cigarette-only users (OR = 1.21, 95% CI: 0.64,2.26). No significant effect on quitting was seen for chewing tobacco use, either before (OR = 1.51, 95% CI: 0.83,2.78) or after (OR = 1.36, 95% CI: 0.87,2.13) cigarette use, compared to cigarette-only users. When the two forms of SLT were combined, no significant effect on quitting was found, either for SLT use before (OR = 1.28, 95% CI: 0.76,2.16) or after (OR = 1.45, 95% CI: 0.96,2.20) cigarettes compared to cigarette-only use.

DISCUSSION

A possible causal gateway effect of SLT use on cigarette smoking is of understandable concern to policy makers, and some authorities have acted as if there is an established gateway effect (e.g. Ferrence *et al.* 2001; Haddock *et al.* 2001; Stratton *et al.* 2001; Tomar 2002, 2003), but it is crucial to consider the extent of the problem. If only a small subset of youth fall victim to a causal gateway (i.e. would not have started smoking if not for prior use of SLT), the policy implications may be relatively minor. The large majority of SLT use (77%) appears not to be a causal gateway to cigarettes and, further, policymakers seem to have ignored the countervaling prospect that some users of SLT might be prevented from smoking because of SLT. Given the pattern of results (i.e. non-gateway uses much more common than gateway uses), it is possible that SLT has greater smoking preventive than smoking causative effects. To focus only on putative gateway effects neglects possible benefits of SLT for individuals at highest risk of taking up smoking. We think that both proponents and opponents of SLT for harm reduction would benefit from the analytical exercise of thinking of alternative explanations for either SLT as causing smoking or SLT as preventing smoking based solely on the sequence of product use (or lack thereof). Although sequence of use alone cannot establish causation or prevention, the analyses we have presented can help rule out causation.

Our results support those of Ramström (1990, 2001), despite large differences in base-rates of SLT use. Subsequent to our analyses, we located a marketing study done by Philip Morris in the early 1980s (Miller 1984). Interviewers asked 236 18-34-year-old SLT users in Houston, Atlanta and Florida whether they had ever smoked and, if so, which product they had used first. Overall, 53% ($n = 125$) used SLT only, 26% ($n = 61$) used cigarettes before SLT, for a total of 79% non-causal gateway use, and 21% ($n = 50$) used SLT before cigarettes (Miller 1984). This represents another basic replication of the finding of a majority non-gateway effect for SLT.

Tomar's analysis of adult NHIS data from 1998 (Tomar 2002) found that males were 2.5 times more likely to be former snuff users who currently smoked than to be former smokers who currently used snuff (2.5% versus 1%). We found a similar pattern (2.2% versus 0.8%) in the NHIS data from 1987 (ages 18–98). At the same time, the data reported on order of first use allows a more refined, process-orientated look at the phenomena in question and does not support a strong gateway effect from SLT to cigarettes.

The age cohort effects do not support the 'gateway' fear that increased SLT use leads to increased smoking. Although there was an increase in SLT use in younger cohorts, this increase is associated with a decrease in smoking, not an increase. This was true, having eliminated the young people who might reasonably still move from SLT only use to SLT first use. The cohort finding also raises doubt that increases in use of smokeless tobacco will lead generally to increases in cigarette smoking. Rather, they lend support to the idea that SLT may be preventing some would-be smokers from smoking.

Levels of snuff and chewing tobacco use were similar. Our logistic regression analyses of smoking cessation showed effects only for those snuff users who used cigarettes first; no effect was seen when a combined SLT use variable was used. It may be premature to focus on just snuff or to collapse snuff and chewing tobacco into one category in surveys, as was the case in the Teenage Attitudes and Practices Survey (TAPS) (Moss *et al.* 1992).

There are limitations to our study beyond those already noted. Recalled age of first use or even regular use of a tobacco product may have limited reliability or validity. Complex patterns of early starting and stopping could not be assessed. For example, it is possible that the age at daily or heavy use of SLT or cigarettes is not related directly to age at first use or even age at 'regular' use. If one can be sure that the prior use of cigarettes was long-standing and heavy, one could be confident that SLT did not cause cigarette smoking; however, if the prior use of cigarettes was minimal, followed by heavy use of SLT that then led to smoking, it would be wrong to rule out a possible SLT gateway effect. Direct questions were never

asked about what the individual thought about his or her transitions in tobacco use. How many of those who used SLT first switched to cigarettes to try to achieve greater pharmacological satisfaction or because of greater convenience of use? How many who switched to cigarettes were unaware that they were substantially increasing risks of disease and death? No information is available from this dataset on these important questions.

Another important question is how many of those who switched from cigarettes to SLT were using SLT intentionally to substitute for cigarettes. A cigarette company conducted in-store interviews (Miller 1984) of former smokers (96/180) in Texas, Georgia and Florida, and found that 53% said 'yes' to the question, 'Did you start smokeless/chewing tobacco as a replacement for cigarettes, that is, when you stopped smoking cigarettes, or not?' (Miller 1984). Similarly, Cohen-Smith and Severson (1999) found that 58.8% of men in their study reported using SLT as a replacement for cigarettes when they were quitting smoking. Asking such direct questions as part of the NHIS survey would provide direct means for policy makers to assess the use of SLT for smoking cessation. To evaluate smoking preventive effects of SLT, it would be helpful to know if users thought they might use cigarettes if SLT were not available.

The gateway hypothesis seems to be supported by the pharmacological principle that faster-acting drug forms are preferred to slower-acting drug forms (USDHHS 1988; Russell & Feyerabend 1978). However, the present finding that many smokeless users do not progress to cigarettes encourages a closer look at this prevailing belief. Context also contributes to drug preferences (Kozlowski 1982). Public health concern about public spitting may have contributed as much to the decline of smokeless use and the rise of the cigarette in the early 20th century, as did the more rapid pharmacokinetics of inhaled cigarette smoke. We were surprised to learn from a report in the tobacco documents that 62% of respondents who used both smokeless and cigarettes reported that smokeless/chewing tobacco was 'more enjoyable' than cigarettes (Miller 1984).

Remember also that these are historical patterns of use. For policy, it is important to realize that various interventions might influence rates of use. For example, health organizations can emphasize the greater dangers of cigarettes in comparison to smokeless (Kozlowski & O'Connor 2003). Governments can tax products differentially, with greater taxes on more dangerous products, providing an economic incentive for harm reduction. Any gateway effects are likely to be influenced by such interventions, and could be minimized with proper policy implementation.

Overall, our findings argue for a reduced emphasis on causal gateway effects for smokeless tobacco on cigarette smoking. Science-based policy makers should also consider that SLT use can actively prevent smoking in some high-risk users, and such a potential harm-reducing effect needs to be weighed against those individuals who might become smokers because of prior use of SLT.

ACKNOWLEDGEMENTS

Thanks go to John W. Graham, Laura C. Klein and Spring C. Cooper for their critical readings of earlier drafts of this manuscript.

REFERENCES

Accortt, N. A., Waterbor, J. W., Beall, C. & Howard, G. (2002) Chronic disease mortality in a cohort of smokeless tobacco users. *American Journal of Epidemiology*, **156**, 730–737.

Altman, D. G., Machin, D., Bryant, T. N. & Gardner, M. J., eds. (2000) *Statistics with Confidence*, 2nd edn. London: BMJ Books.

Baumrind, D. (1983) Specious causal attributions in the social sciences: the reformulated stepping-stone theory of heroin use as exemplar. *Journal of Personality and Social Psychology*, **45**, 1289–1298.

Cohen-Smith, D. & Severson, H. H. (1999) A comparison of male and female smokeless tobacco use. *Nicotine and Tobacco Research*, **1**, 211–218.

Davis, J. A. (1985) *The Logic of Causal Order*. Sage university papers. Quantitative applications in the social sciences, no. 07–055. Beverly Hills, CA: Sage.

Ferrence, R., Slade, J., Room, R. & Pope, M., eds (2001) *Nicotine and Public Health*. Washington DC: American Public Health Association.

Griffin, K. W., Botvin, G. J., Doyle, M. M., Diaz, T. & Epstein, J. A. (1999) A six-year follow-up study of determinants of heavy cigarette smoking among high-school seniors. *Journal of Behavioral Medicine*, **22**, 271–284.

Haddock, C. K., van der Weg, M., DeBon, M., Klesges, R. C., Talcott, G. W., Lando, H. & Peterson, A. (2001) Evidence that smokeless tobacco use is a gateway for smoking initiation in young adult males. *Preventive Medicine*, **32**, 262–267.

Hatsukami, D. K., Jensen, J., Boyle, R., Grillo, M. & Bliss, R. (1999) Characteristics of smokeless tobacco users seeking treatment. *Addictive Behaviors*, **24**, 551–557.

Kandel, D. B. & Jessor, R. (2002) The gateway hypothesis revisited. In: Kandel, D. B., ed. *Stages and Pathways of Drug Involvement: Examining the Gateway Hypothesis*, pp. 365–372. Cambridge: Cambridge University Press.

Kozlowski, L. T. (1982) The determinants of tobacco use: cigarette smoking in the context of other forms of tobacco use. *Canadian Journal of Public Health*, **73**, 236–241.

Kozlowski, L. T. & Harford, M. R. (1976) On the significance of never using a drug: an example from cigarette smoking. *Journal of Abnormal Psychology*, **85**, 433–434.

Kozlowski, L. T. & O'Connor, R. J. (2003) Apply federal research rules on deception to misleading health information: an example on smokeless tobacco and cigarettes. *Public Health Reports*, **118**, 187–192.

Lewin, F., Norell, S. E., Johansson, H., Gustavsson, P., Wennerberg, J., Biorklund, A. & Rutqvist, L. E. (1998) Smoking tobacco, oral snuff, and alcohol in the etiology of squamus cell carcinoma of the head and neck: a population-based case-referent study in Sweden. *Cancer*, **82**, 1367–1375.

McNeill, A. D. (1990) Bandits on the run: the oral snuff debate. *British Journal of Addiction*, **85**, 1095–1096.

Miller, K. (1984) Smokeless tobacco study—Atlanta/Florida. Philip Morris USA, 1984. Available at http://www.pmdocs.com [Bates no. 2045600026].

Miller, T. Q. (1994) A test of alternative explanations for the stage-like progression of adolescent substance use in four national samples. *Addictive Behaviors*, **19**, 287–293.

Moss, A. J., Allen, K. F., Giovino, G. A. & Mills, S. L. (1992) *Recent Trends in Adolescent Smoking, Smoking-Uptake Correlates, and Expectations About the Future.* Advance Data from Vital and Health Statistics, no. 221. Hyattsville, MD: National Center for Health Statistics.

Murray, D. M., Roche, L. M., Goldman, A. I. & Whitbeck, J. (1988) Smokeless tobacco use among ninth graders in a north-central metropolitan population: cross-sectional and prospective associations with age, gender, race, family structure, and other drug use. *Preventive Medicine*, **17**, 449–460.

National Cancer Institute (1992) *Smokeless Tobacco or Health: An International Perspective.* Bethesda, MD: US Department of Health and Human Services, National Institutes of Health, National Cancer Institute.

Nordgren, P. & Ramström, L. (1990) Moist snuff in Sweden—tradition and evolution. *British Journal of Addiction*, **85**, 1107–1112.

Ramström, L. (1990) Smokeless tobacco—a potential gateway to smoking? *Proceedings of the 7th World Conference on Tobacco or Health, Perth, Australia*, pp. 451–452.

Ramström, L. (2000) Snuff—an alternative nicotine delivery system. In: R. Ferrence, J. Slade, R. Room & M. Pope, eds. *Nicotine and Public Health*, pp. 159–178. Washington, DC: American Public Health Association.

Research Triangle Institute (2002) *SUDAAN Software for the Statistical Analysis of Correlated Data*, release 8.0.1. [computer software]. Research Triangle Park, NC: Research Triangle Institute.

Russell, M. A. & Feyerabend, C. (1978) Cigarette smoking: a dependence on high-nicotine boli. *Drug Metabolism Review*, **8**, 29–57.

Schoenborn, C. A. & Boyd, G. (1989) *Smoking and Other Tobacco Use: United States, 1987.* Vital Health Statistics, 10. Hyattsville, MD: National Center for Health Statistics.

Stratton, K., Shetty, P., Wallace, R. & Bondurant, S., eds (2001) Clearing the smoke: assessing the science base for tobacco harm reduction. Washington, DC: Institute of Medicine, National Academy Press.

Tomar, S. L. (2002) Snuff use and smoking in U.S. men: implications for harm reduction. *American Journal of Preventive Medicine*, **23**, 143–149.

Tomar, S. L. (2003) Is use of smokeless tobacco a risk factor for cigarette smoking? *The U.S. Experience. Nicotine and Tobacco Research*, in press.

Tomar, S. L. & Giovino, G. A. (1998) Incidence and predictors of smokeless tobacco use among U.S. youth. *American Journal of Public Health*, **88**, 20–26.

United States Department of Health and Human Services (USDHHS) (1988) *Nicotine Addiction*. A Report of the Surgeon General. Rockville, MD: US Department of Health and Human Services, Public Health Service, Centers for Disease Control.

United States Department of Health and Human Services (USDHHS) (1994) *Preventing Tobacco Use Among Young People*. A Report of the Surgeon General. Rockville, MD: US Department of Health and Human Services, Public Health Service, Centers for Disease Control.

United States Department of Health, Education and Welfare (USDHEW) (1964) *Smoking and Health*. Report of the Advisory Committee to the Surgeon General of the Public Health Service, 1964. Public Health Publication no. 1103.

United States Department of Health and Human Services (USDHHS) (1987) *National Health Interview Survey*. Atlanta, GA: USDHHS, Centers for Disease Control and Prevention, National Center for Health Statistics.