Prevalence of Heavy Smoking in California and the United States, 1965-2007

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Context The intensity of smoking, not just prevalence, is associated with future health consequences.

Objective To estimate smoking intensity patterns over time and by age within birth cohorts for California and the remaining United States.

Design, Setting, and Participants Two large population-based surveys with state estimates: National Health Interview Surveys, 1965-1994; and Current Population Survey Tobacco Supplements, 1992-2007. There were 139 176 total respondents for California and 1 662 353 for the remaining United States.

Main Outcome Measure Number of cigarettes smoked per day (CPD), high-intensity smokers (≥20 CPD); moderate-intensity smokers (10-19 CPD); low-intensity smokers (0-9 CPD).

Results In 1965, 23.2% of adults in California (95% confidence interval [CI], 19.6%-26.8%) and 22.9% of adults in the remaining United States (95% CI, 22.1%-23.6%) were high-intensity smokers, representing 56% of all smokers. By 2007, this prevalence was 2.6% (95% CI, 0.0%-5.6%) or 23% of smokers in California and 7.2% (95% CI, 6.4%-8.0%) or 40% of smokers in the remaining United States. Among individuals (US residents excluding California) born between 1920-1929, the prevalence of moderate/high-intensity smoking (≥10 CPD) was 40.5% (95% CI, 38.3%-42.7%) in 1965. Moderate/high-intensity smoking declined across successive birth cohorts, and for the 1970-1979 birth cohort, the highest rate of moderate/high-intensity smoking was 9.7% (95% CI, 7.7%-11.7%) in California and 18.3% (95% CI, 16.4%-20.2%) in the remaining United States. There was a marked decline in moderate/high-intensity smoking at older ages in all cohorts, but this was greater in California. By age 35 years, the prevalence of moderate/high-intensity smoking in the 1970-1979 birth cohort was 4.6% (95% CI, 3.0%-6.1%) in California and 13.5% (95% CI, 11.8%-15.1%) in the remaining United States.

Conclusions Between 1965 and 2007, the prevalence of high-intensity smoking decreased greatly in the United States. The greater decline in high-intensity smoking prevalence in California was related to reduced smoking initiation and a probable increase in smoking cessation.

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THROUGHOUT MUCH OF THE early history of cigarette smoking in the United States, modal consumption was 1 pack of cigarettes each day.[1] Since the first surgeon general's report on smoking and health (1964),[2] there has been a major decline in smoking prevalence from 40.4% in 1965[1] to 20.8% in 2006.[3] During this period, California consistently led the United States in using public policies to reduce cigarette smoking, and there were faster declines in smoking prevalence in California compared with the remaining United States (0.74% per year vs 0.53% per year, respectively) as well as in lung cancer rates (2007 rates: California, 77.1/100 000 vs the remaining United States, 101.7/100 000).[4] Lung cancer risk is related to both the duration of smoking and the intensity of consumption,[5,6] and population changes in initiation, cessation, and amount smoked are reflected in age-specific smoking intensity patterns.

This article reports trends in smoking intensity for both California and the remaining United States using population-based surveys conducted from 1965-2007. This study considers how age-related patterns in higher-intensity smoking have changed across birth cohorts and draws inferences on the role of smoking initiation and cessation.

METHODS

Surveys

We used 2 national household surveys to estimate smoking intensity in US adults for 1965-2007. The National Health Interview Surveys (NHIS) and the Tobacco Use Supplements to the Current Population Survey (TUS-CPS) both use a complex multistage sampling design. Prior to a policy change in 1995, state-specific codes were provided for the 1965-1994 NHIS data. These 18 surveys had annual household sample sizes of 35 000 to 45 000 and reported overall (screener)

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response rates of approximately 80%.[1] Six TUS-CPS were conducted between 1992-2007 with monthly household sample sizes of approximately 50 000 to 60 000; each tobacco supplement included 3 monthly samples. The TUS-CPS provided state-specific smoking estimates with adult response rates greater than 65%.[7] To diminish bias, each survey published weights that were used to adjust for undercoverage among age, sex, and race/ethnicity categories.[7,8]

Definition of Smoking

In both surveys, ever-smoking is defined as lifetime smoking of at least 100 cigarettes and a follow-up question identifies current smokers. In 1992, the current smoking question was modified in each survey to distinguish nondaily and daily smokers, a change that was associated with a 1- to 3-percentage point increase in smoking prevalence.[9] After 1992, nondaily smokers reported the number of days smoked in the previous month, and the average cigarettes smoked on smoking days. Daily smokers reported the average number of cigarettes smoked each day.

Population Prevalence Measures

Our analysis uses only self-reported data from respondents aged 18 years and older. High-intensity smoking was defined as smoking an average of at least 20 cigarettes per day (CPD), moderate-intensity smoking as 10 to 19 CPD, and low-intensity smoking as 0 to 9 CPD. For each survey, the prevalence of smoking at each intensity level was computed separately for California and the remaining United States.

Birth Cohorts

To investigate changes in smoking intensity, we grouped respondents into 10-year birth cohorts starting with the decade 1920-1929. Following previous research,[10] we computed point prevalence estimates within each survey and birth cohort, and then investigated the age-specific pattern within each birth cohort using regression models. For these models, the birth cohort as a whole was assigned the midpoint of the approximately 10-year age range attained within the survey year.

Statistical Methods

Computations were carried out using SAS statistical software, version 9.2 (SAS Institute Inc, Cary, North Carolina). All point estimates were weighted using the published weights for each survey series. The variance of each NHIS point estimate was computed using a domain analysis with a Taylor series approximation as recommended in the survey documentation[8]; for point estimates from the TUS-CPS, the recommended resampling-based method with published replicate weights was used.[11]

Least-squares regression was used to estimate time trends, weighting each data point by its inverse variance to incorporate the estimated sampling variability. To account for nonlinear patterns, the time trends were modeled using first-degree regression splines. For the birth cohort estimates, breakpoints were allowed every 5 years starting at age 20 years, except in California, where the first breakpoint in every cohort was omitted because of small sample sizes. For the prevalence estimates, breakpoints were allowed at 1979, 1989, and 1999, and separate trends were estimated for California and for the remaining United States. Two-sided tests of the difference between California and the remaining United States were used and the model allowing for separate time trends was compared with a model that did not distinguish between California and the remaining United States using an F test at the 5% significance level. Fitted values and their 95% confidence intervals (CIs) were computed from the models.

RESULTS

For the 18 NHIS conducted from 1965-1994, the number of adult respondents from California ranged from 352 to 2577, while for the remaining United States, sample sizes ranged from 3052 to 35 181. For the 6 TUS-CPS conducted between 1992 and 2007, sample sizes ranged from 1462 to 3048 in California and 40 262 to 50 489 in the remaining United States. Total participants included 28 866 for California and 423 300 for the remaining United States. Sample sizes for birth cohorts ranged from 2067 to 6144 for California and from 37 153 to 84 460 for the remaining United States (eTable 1 available at http://www.jama.com). Comparison of national trends for the 3 smoking intensity levels across the 2 surveys supported the decision to combine them into a single analysis (eFigure 1, eFigure 2, and eFigure 3).

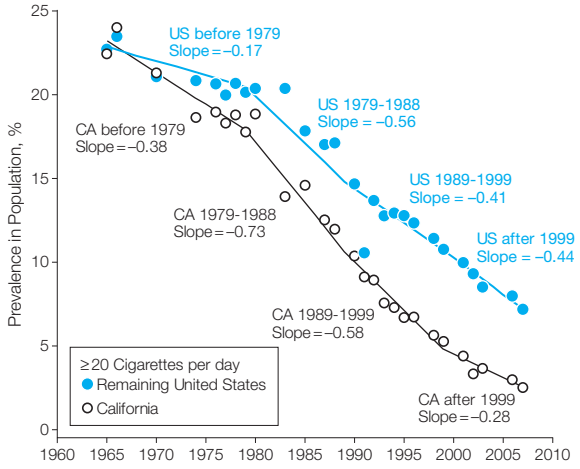
Trends in Prevalence by Smoking Intensity

High-Intensity Smoking. From 1965-2007, the regression model (FIGURE 1) using the combined survey data (eTable 2) indicated that the decline in high-intensity smoking was greater in California than in the remaining United States ($F_{5,44}=19.4$; $P<.001$). In 1965, the modeled prevalence of high intensity of smoking among California adults did not differ from the remaining United States; prevalence of high-intensity smoking in California was 23.2% (95% CI, 19.6%-26.8%) compared with 22.9% (95% CI, 22.1%-23.6%) in the remaining United States, and these smokers represented 56% of all smokers. By 1979, the prevalence of high-intensity smoking in California was 17.9% (95% CI, 14.7%-21.2%) compared with 20.5% (95% CI, 19.4%-21.5%) in the remaining United States—a difference of 2.6 percentage points. By 1989, the prevalence of high-intensity smoking in California was 10.6% (95% CI, 8.4%-12.8%) vs 14.8% (95% CI, 14.1%-15.5%) in the remaining United States—a difference of 4.2 percentage points. By 1999, this prevalence was 4.8% (95% CI, 2.6%-7.0%) in California compared with 10.7% (95% CI, 10.1%-11.3%) in the remaining United States—a difference of 5.9 percentage points. By 2007, this prevalence was 2.6% in California (95% CI, 0.0%-5.6%) and 7.2% in the remaining United States (95% CI, 6.4%-8.0%), a difference of 4.6 percentage

points. Thus, in 2007, the prevalence of high-intensity smokers in California was 11.2% of the 1965 level, whereas for the remaining United States, it was 31.4%.

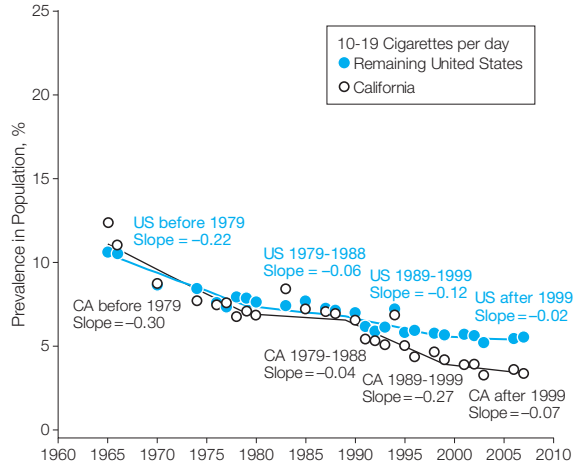
Moderate-Intensity Smoking. In 1965, the modeled population prevalence of moderate-intensity smoking was 11.1% in California (95% CI, 9.5%-12.6%) and 10.5% in the remaining United States (95% CI, 10.2%-10.8%) (FIGURE 2). The pattern of change from 1965 to 2007 differed significantly between California and the remaining United States ($F_{5,44}$=28.0; $P<.001$), although the difference appears mainly after 1989. By 1989, the prevalence of moderate-intensity smoking was 6.6% in California (95% CI, 5.7%-7.5%) compared with 6.8% in the remaining United States (95% CI, 6.5%-7.1%), a nonsignificant difference. However, by 1999, the prevalence was 3.9% in California (95% CI, 3.0%-4.8%), which was significantly lower than the prevalence of 5.6% in the remaining United States (95% CI, 5.3%-5.8%) as indicated by nonoverlapping CIs. Similarly, a difference in moderate-intensity smoking prevalence between California and the remaining United States persisted through 2007 when the prevalence in California was 3.4% (95% CI, 2.2%-4.6%) compared with 5.4% in the remaining United States (95% CI, 5.0%-5.7%).

Figure 1. Prevalence of High-Intensity Smoking, 1992-2007



Weighted trends in prevalence of high-intensity smoking (≥20 cigarettes per day [CPD]) in California (CA) and the remaining United States, 1965-2007. Data from National Health Interview Surveys 1965-1994 and Current Population Survey Tobacco Supplements 1992-2007. Reported slopes indicate percentage points per year.

Figure 2. Prevalence of Moderate-Intensity Smoking, 1992-2007



Weighted trends in percent prevalence of moderate-intensity smoking (10-19 cigarettes per day [CPD]) in California (CA) and the remaining United States, 1965-2007. Data from National Health Interview Surveys 1965-1994 and Current Population Survey Tobacco Supplements 1992-2007. Reported slopes indicate percentage points per year.

Low-Intensity Smoking. In 1965, the population prevalence of low-intensity smoking was 7.1% in California (95% CI, 6.1%-8.2%) and 7.0% in the remaining United States (95% CI, 6.7%-7.2%), and the pattern of change in prevalence over the next 4 decades appears similar between California and the remaining United States (FIGURE 3). Low-intensity smoking declined slightly in both settings through 1989. In 1992, an increase in the prevalence of low-intensity smoking associated with a change in survey question wording was observed. In 2007, the prevalence of low-intensity smokers was 5.3% in both California (95% CI, 4.2%-6.3%) and the remaining United States (95% CI, 5.0%-5.5%), which represented approximately half of the smokers in California (48%) and approximately one-third of smokers in the remaining United States (29%).

To summarize, adding the modeled prevalence of high-, moderate-, and low-intensity smokers in 2007, 11.3% (2.6% + 3.4% + 5.3%, respectively) of California adults were smokers, 23% of whom were high-intensity smokers. In the same year, 17.9% (7.2% + 5.4% + 5.3%) of adults in the remaining United States were smokers, 40% of whom were high-intensity smokers.

Prevalence of Moderate/High-Intensity Smokers by Birth Cohort

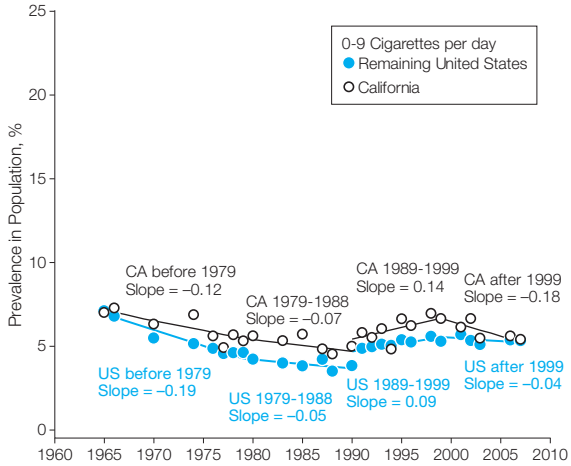
The repeated cross-sectional surveys allow modeling of the trajectory of moderate/high-intensity smoking (≥10

CPD) with increasing age and this is presented by birth cohort for California (FIGURE 4) and the remaining United States (FIGURE 5). Point estimates of smoking at 25 years of age are only available for those cohorts born after 1940, as the first survey was conducted in 1965. For the 1940-1949 and 1950-1959 birth cohorts (remaining United States), the modeled pattern appears to be an increase in 10 or more–CPD smoking with age through respondents' 20s and early 30s, after which prevalence stabilized and then declined. However, in cohorts born after 1960, there was no increase in the prevalence of 10 or more–CPD smoking through the young adult years. The rapid increase seen between ages 15 and 20 years in later birth cohorts is expected as these are peak smoking initiation years.

At 43 years of age (first available survey), the modeled prevalence of 10 or more–CPD smoking in the 1920-1929 birth cohort was 39.2% in California (95% CI, 33.8%-44.6%) and 40.5% for the remaining United States (95% CI, 38.3%-42.7%). Peak prevalence declined with each younger birth cohort, with greater declines in California than the remaning United States. The 1940-1949 birth cohort peak prevalence occurred at 24 years of age in California (32.5%; 95% CI, 30.6%-34.4%) and at 30 years of age in the remaining United States (37.4%; 95% CI, 35.3%-39.6%). In the 1950-1959 birth cohort, peak prevalence in California (27.2%; 95% CI, 21.1%-33.4%) was 13% lower than in the remaining United States (31.2%; 95% CI, 25.1%-37.3%) and the difference in peak prevalence between California and the remaining United States increased to 43% among members of the 1960-1969 birth cohort (15.6%; 95% CI, 8.8%-22.4%) vs 27.7% (95% CI, 17.8%-37.6%) and 47% among members of the 1970-1979 birth cohort (9.7%; 95% CI, 7.7%-11.7%) vs 18.3% (95% CI, 16.4%-20.2%).

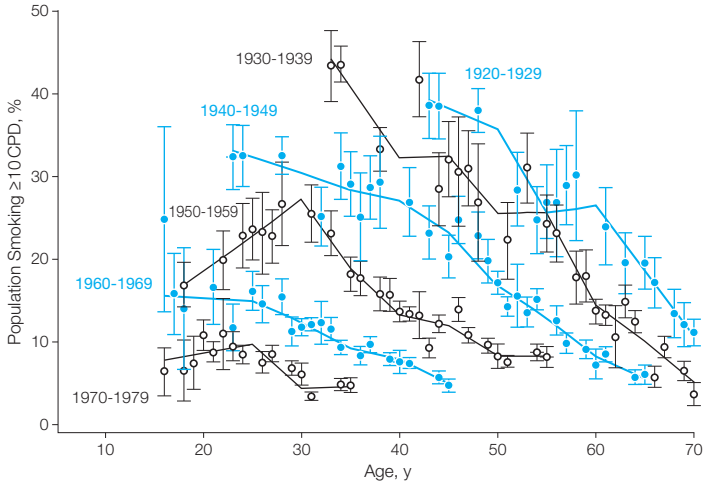
The modeled prevalence of moderate/high-intensity smoking declined at older ages within each birth cohort. For the 1920-1929 birth cohort, by 65 years of age, prevalence had declined by more than half from the highest prevalence both in California (18.4%; 95% CI, 14.5%-22.4%) and in the remaining United States (21.1%; 95% CI, 18.7%-23.5%). For the 1940-1949 cohort, this prevalence at 65 years of age had declined to 5.7% (95% CI, 4.1%-7.2%) in California and 11.5% (95% CI, 10.9%-12.0%) in the remaining United States. For the 1950-1959 birth cohort at 55 years of age (oldest age available), the prevalence had declined to 8.3% (95% CI, 6.6%-10.0%) in California compared with 14.9% (95% CI, 13.1%-16.6%) in the remaining United States. Prevalence was even lower in the 1970-1979 birth cohort by 35 years of age (California, 4.6%; 95% CI, 3.0%-6.1%; remaining United States, 13.5%; 95% CI, 11.8%-15.1%).

Figure 3. Prevalence of Low-Intensity Smoking, 1992-2007



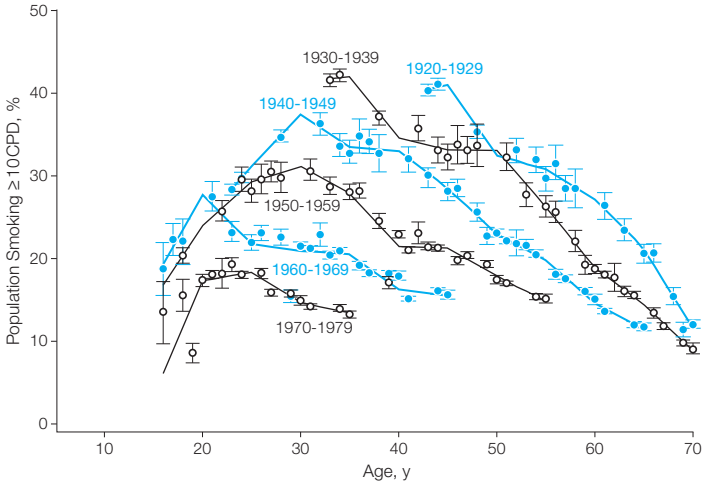
Weighted trends in percent prevalence of low-intensity smoking (0-9 cigarettes per day [CPD]) in California (CA) and the remaining United States, 1965-2007. Data from National Health Interview Surveys 1965-1994 and Current Population Survey Tobacco Supplements 1992-2007. Reported slopes indicate percentage points per year.

Figure 4. California Smoking Prevalence by Birth Cohort and Age



Weighted percent prevalence of moderate/high-intensity smoking (≥10 cigarettes per day [CPD]) by birth cohort and age in California. Error bars indicate 95% confidence intervals on point estimates.

Figure 5. US Smoking Prevalence by Birth Cohort and Age Excluding California



Weighted percent prevalence of moderate/high-intensity smoking (≥10 cigarettes per day [CPD]) by birth cohort and age for United States excluding California's population. Error bars indicate 95% confidence intervals on point estimates.

COMMENT

Over the past 40 years, high-intensity smoking (smoking ≥20 CPD) has declined markedly in both California and the remaining United States from 56% of all smokers in 1965 to only 23% of smokers in California and 40% of smokers in the remaining United States in 2007. This decline in high-intensity smoking was not accompanied by a compensatory increase in the prevalence of less intense smoking and has been brought about by changes in the pattern of smoking across birth cohorts.

The NHIS and CPS-TUS surveys provide multiple independent cross-sectional assessments of smoking behavior within each birth cohort and allow inferences regarding changes in population smoking patterns with age. There is considerable evidence that smoking initiation is complete by 25 years of age[1,12] so that increases in the prevalence of moderate- or higher-intensity smoking after this age reflect increases in consumption among continuing smokers within a birth cohort. Among 1940-1959 birth cohorts in both California and the remaining United States, 10 or more–CPD smoking prevalence peaked at approximately 30 to 35 years of age, with more than 40% of these cohorts smoking at least 10 CPD. In these earlier birth cohorts, smokers appeared to progress to 10 or more–CPD smoking between 20 and 30 years of age; however, this progression was not observed in younger birth cohorts Additionally, across successive birth cohorts, there was a major decline in the proportion of the cohort who in their early 20s were 10 or more–CPD smokers. Among younger cohorts (1960-1979), the peak proportion of 10 or more–CPD smokers occurred before 25 years of age, with this peak in the 1970-1979 cohort from California being slightly more than half (53%) that of the remaining United States (9.7% vs 18.3%). Thus, there has been a major decline in initiation of 10 or more–CPD smoking in the United States, particularly in California.

Within all birth cohorts, as the cohort aged there was a major decline from the peak prevalence of 10 or more–CPD smoking, which would appear to be mainly attributable to cessation as there is no compensating increase in lower smoking categories. The earliest birth cohort studied (1920-1929) were in their 20s in 1950 when the first reports on smoking and cancer appeared in the medical literature. The rapid decline in prevalence of 10 or more–CPD smoking across birth cohorts in the mid-1960s is consistent with earlier reports of increased incidence of cessation that occurred following the dissemination of the early scientific reports that smoking caused cancer.[13]

There are a number of reasons why the decline in 10 or more–CPD smokers has been greater in California than in the remaining United States, including California's comprehensive tobacco control programs.[14,15] In 1968, California was the first state to aggressively raise its cigarette tax,[16] and throughout the 1968-2007 period, the price of cigarettes was higher in California than the average for the remaining United States (although there are many states with higher prices than California).[4] Furthermore, California was the first state to introduce an ongoing, well-funded comprehensive tobacco control program, which has been in place since 1989.[4,14] Ordinances restricting cigarette smoking in the workplace were first introduced in California in 1976[17] and increased rapidly throughout the 1980s. In 1994, these were replaced with the first statewide smoke-free workplace law, which was associated with increased voluntary restrictions on smoking in the home.[18] Population norms supporting smoke-free environments in the remaining United States have consistently lagged behind California.[19] Some of these changes may be associated with substantial growth in California of subpopulations (Latino and Asian individuals) with markedly different smoking patterns.[20] However, it has previously been shown that the increasing differences in consumption observed over the past 20 years have been observed across all population subgroups[21] so that demographic changes do not explain the differential trends.

As expected, the large decline in the prevalence of pack-a-day smoking has been reflected in declines in lung cancer. Lung cancer death rates peaked in California in 1987 at 109 per 100 000

and declined continuously to 77 per 100 000 in 2007. In the remaining United States, lung cancer deaths peaked in 1993 at 117 per 100 000 and declined to 102 per 100 000 by 2007.[4] Thus, the peak lung cancer rates occurred 13 to 17 years after the apparent peak in prevalence of high-intensity smoking. Previous research has demonstrated that high-intensity smokers have much higher future risk of lung cancer even after years of successful cessation[22] and that high-intensity smokers who reduce their consumption by 50% do not achieve the risk level of a smoker who never smoked heavily.[23,24] As it now appears that less than 10% of young Californians and less than 20% of young residents in the remaining United States will ever reach these high-intensity levels of cigarette consumption, lung cancer rates should continue to decrease, with a continued widening of the difference in rates between California and the remaining United States.

The large decline in 10 or more–CPD smokers, particularly in California, has implications for smoking cessation as well. That 48% of Californian smokers consume less than a half pack per day suggests that further study is needed to identify whether there may have been a decline in the level of physiological dependence on nicotine, although changes in inhalation patterns, for example, could facilitate maintenance of high nicotine levels despite smoking fewer CPD. One puzzling anomaly in recent years is that population research does not support the evidence from clinical trials on the benefits of pharmacotherapies to increase successful cessation.[25,26] However, the majority of these clinical trials enrolled only individuals who smoked 15 or more CPD. The anomaly could be explained if in the population, quitters come mainly from lower-intensity smoking categories for whom pharmacotherapies appear to be less effective.[27,28] Previous research has demonstrated that there may be significant reduction in smoking among high-intensity smokers prior to quitting.[29] Much of the reduction in 10 or more–CPD smoking appears to have come from younger birth cohorts who never reached the higher-intensity smoking levels of previous cohorts. However, all cohorts have reached low proportions of 10 or more–CPD smokers in recent surveys. This suggests that population strategies should concentrate more on cessation strategies that are likely to be successful with low-intensity smokers including smoke-free policies.[30]

A strength of this study is the use of 2 large national population-based surveys that provide data on smoking prevalence and intensity across a 42-year span. Although smoking was not the primary focus of either survey, use of contemporary reports of current smoking consumption levels across time and age enabled the construction of smoking intensity trajectories within birth cohorts.

Limitations of the survey data include the potential for response bias that could affect estimates of smoking prevalence. While these 2 federal government surveys have fared better than others, response rates for all surveys have declined over time and may be associated with increasing risk of bias in the later survey years. However, a study of different contemporaneous, large population surveys with very different response rates indicated that smoking status was not related to response rate.[31] Neither survey included biological verification of smoking status although previous studies have validated self-reported estimates from population surveys using cotinine testing[32] as well as reporting by significant others.[33] Concern about the validity of the survey data may be further mitigated by the finding that relative differences in cigarette consumption between California and the remaining United States have been found to be similar in analyses of data from self-reported surveys of cigarette use and government reports of taxed cigarette sales for most of this period.[4]

In summary, over the past 40 years, patterns of smoking have changed dramatically in the United States and reflect both reduced initiation and increased cessation. In the 1960s, smoking of 20 or more CPD was the habit of a majority of smokers and population prevalence of this level of smoking was 23%. Since then, the population prevalence of 20 or more–CPD smoking has declined rapidly across the United States, and more quickly in California than the remaining United States. Among younger birth cohorts, only a small minority of the population is expected to ever attain cigarette consumption levels of even 10 or more CPD. Further study of these changes in the intensity of smoking patterns should assess the relative importance of changes in initiation, cessation, and reduced consumption in the documented decline of health consequences of smoking in the United States.

Author Contributions: Dr Pierce had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Pierce, Messer.
Acquisition of data: Pierce, Cowling.
Analysis and interpretation of data: Pierce, Messer, White, Thomas.
Drafting of the manuscript: Pierce, Messer, Thomas.
Critical revision of the manuscript for important intellectual content: Pierce, Messer, White, Cowling, Thomas.
Statistical analysis: Messer, White.
Obtained funding: Pierce, Messer.
Administrative, technical, or material support: Pierce, Messer.
Study supervision: Pierce, Messer.
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Online-Only Content: eTable 1, eTable 2, and eFigures 1, 2, and 3 are available at http://www.jama.com.

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