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Prevalence and determinants of cigarette smoking relapse among US adult smokers - a longitudinal study

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Prevalence and determinants of cigarette smoking relapse among US adult smokers - a longitudinal study

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ABSTRACT

Objectives: This research project aims at estimating the prevalence of cigarette smoking relapse and determine its predictors among adult former smokers in the United States (US).

Setting: This research analysed secondary data retrieved from the Tobacco Use Supplement-Current Population Survey (TUS-CPS) 2010-11 cohort in the US.

Participants: Out of 18,499 participants responded to the survey in 2010 and 2011, the analysis included a total sample size of 3,258 ever smokers, who were living in the US and reported quitting smoking in 2010. The survey's respondents who never smoked or reported current smoking status in 2010 were excluded from the study sample.

Primary and secondary outcome measures: Smoking relapse was defined as picking up smoking in 2011 after reporting smoking abstinence in 2010. The prevalence of relapse over the 12-month follow-up period was estimated in different subgroups. Multivariable logistic regression models were applied to determine factors associated to relapse.

Results: A total of 184 former smokers reported smoking relapse by 2011 (weighted prevalence: 6.8%. 95%CI: 5.7%-8.1%). Prevalence and odds of relapse were higher among young people compared to elders. Former smokers living in smoke-free homes had 60% lower odds of relapse compared with those living in homes that allowed smoking inside (aOR:0.40; 95%CI: 0.25-0.64). Regarding race/ethnicity, only Hispanics had significantly higher odds of relapse compared to whites (non-Hispanics). Odds of relapse were higher among never-married, widowed, divorced and separated individuals compared to the married group. Continuous smoking

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cessation for 6 months or more significantly decreased odds of relapse among the study sample.

Conclusions: Wider health determinants influenced prevalence of smoking relapse among US adults, highlighting the need for targeted interventions.

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ARTICLE SUMMARY

Strengths and limitations of this study

- The data was retrieved from a well structured survey, Tobacco Use Supplement-Current Population Survey (TUS-CPS), that is conducted regularly every 3 to 4 years in the US since 1992.
- The research project follows a secondary data analysis of a longitudinal study, which is compatible with the nature of the investigated subject as smoking relapse after a period of abstinence.
- A sensitivity analysis was conducted to validate the analysis and results of the research project.
- Further research could be conducted in the future considering a larger sample size and adding a qualitative part for investigating the motivations and other determinants that might lead to pick up smoking after cessation.

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LIST OF ABBREVIATIONS

AIC	Akaike information criterion
aOR	Adjusted Odds Ratio
BIC	Bayesian information criterion
CDC	Centres of Disease Control and Prevention
CHD	Coronary Heart Disease
CI	Confidence Interval
COPD	Chronic Obstructive Pulmonary Diseases
CPS	Current Population Survey
CVD	Cardiovascular Diseases
D.C	District of Columbia
FCTC	WHO Framework Convention on Tobacco Control
GDP	Gross Domestic Product
HP2020	Healthy People 2020
N	Number of observations
NCTP	Non-Cigarette Tobacco Products
OR	Unadjusted Odds Ratio
RR	Relative Risk
SFH	Smoke Free Home
TUS	Tobacco Use Supplement
TUS-CPS	Tobacco Use Supplement-Current Population Survey
UK	United Kingdom
US	United States of America
WHO	World Health Organisation

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INTRODUCTION

The World Health Organisation (WHO) estimates there are 1.1 billion current smokers worldwide [1]. According to the Centres for Disease Control and Prevention (CDC) 37.8 million adults were current smokers in the United States (US) in 2016, representing more than 15.5% of the total US population [2 3]. As a result, smoking causes 480,000 deaths annually in the US [4 5], while smoking related costs amount to approximately 1% of the country's Gross Domestic Product (GDP) [6 7].

The prevalence of smoking is determined by the proportion of the non-smoking population that initiates smoking, as well as the proportion of smokers who die or quit. Tobacco control measures aim to reduce smoking prevalence by preventing smoking initiation and increasing successful quit attempts, but long-term cessation is challenging. Although research on smoking cessation is abundant, most studies have explored factors associated with quit intentions and overall determinants of smoking cessation [8-10], with only a few focusing on "relapsing" former smokers who may restart smoking following a quit attempt.

Despite variations in the definitions used in the literature, smoking relapse essentially means picking up smoking after a period of abstinence [11 12]. A previous study estimated that on average, 75% of former smokers relapse at some point during their lifetime [12]. Within the first year of abstinence, relapse rates range from 60% to 90%, while two years of continuous cessation predicted 80% success rate for long-term quitting [13]. In this study, we use cigarette smoking to define relapse, as it is the most common method of tobacco use in the US and globally (>90%) (9). Thus, "smoking" refers to "cigarette smoking".

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Although relapse has rarely been the specific focus of smoking cessation research, it is reasonable to assume that at least some of the factors found to be associated with smoking cessation overall also play a role in the process of relapse. These factors include personal characteristics such as age [14], gender [15], race/ethnicity [16], nicotine dependence [17], individual intentions, and motivations to quit [18 19]. Research has also identified the influence of living in a Smoke-Free Home (SFH) [20], using Non-Cigarette Tobacco Products (NCTP) [21-23] and seeking specialist advice while quitting [24]. A series of recent studies have also indicated a link between social and community circumstances surrounding smokers, and their attitudes toward smoking cessation [25], consistent with evidence on the relationship of smoking with environmental and social-life factors [26 27]. However, hardly any of these studies has assessed these associations for relapse in particular, which remains under-researched.

To fill this gap, this study aims to measure the prevalence of smoking relapse among adult former smokers in the US, and to determine predictors of smoking relapse using a nationally representative longitudinal sample.

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METHODS

Data Source

We conducted a secondary analysis using longitudinal data retrieved from the Tobacco Use Supplement-Current Population Survey (TUS-CPS). This survey has been conducted every 3 to 4 years in the US since 1992. It collects a broad range of data about the US population with topics varying from year to year. For this study, the cohort baseline data was collected in May 2010 and the follow-up survey was conducted in May 2011. It focused on the population's smoking behaviors and cessation attitudes. No other data was recorded between these two time points [28 29].

Selection of TUS-CPS respondents is designed to yield representative estimates for the US overall, as well as the 50 states and Washington, D.C. [30]. Since 2006, the survey has targeted US adults aged 18 years and above [29 30]. Data was collected by telephone or in-person interviews [30]. In the 2010-11 cohort 64% of participants completed the survey by telephone and 36% through in-person interviews [28 30]. Approximately 20% of the data was recorded by proxy, while the rest was self-reported [30]. For this research project, we only used data collected from self-respondents.

The analysis sample comprised individuals who reported being former smokers at baseline (May 2010 survey wave). Their smoking status was self-reported again after one year (May 2011). Relapse was defined as a failure to maintain smoking cessation between the two time points of data collection in the TUS-CPS surveys. Those who didn't report their smoking status in either wave or provided inconsistent data regarding having ever smoked between the two waves were excluded from the analysis. After applying the inclusion and exclusion criteria, the final study sample was 3,258, as illustrated in Figure 1.

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Measures

Smoking relapse status is the principle outcome of this study. Participants were asked to report their smoking status in 2010 and 2011; "*Do you now smoke cigarettes every day, some days, or not at all?*" The answers were categorized into a dichotomous variable (yes [every day or some days] vs no [not at all]). Those who responded "not al all" in 2010, but "every day" or "some days" in 2011 were considered to have relapsed.

Sociodemographic variables included age (18-24, 25-39, 40-65 and ≥65 years); gender (male, female); race/ethnicity (Hispanics, white non-Hispanics, black non-Hispanics, and other non-Hispanics); education level, determined by the highest accomplished level (<high school, high school, some college, defined as partially completed college education, and college or higher); and finally, socioeconomic status, reflected by annual family income (US$ <20k, 20-49k, 50-99k and ≥100k). Categorising these variables was based on previously published reports and studies using the TUS-CPS surveys [31].

This study used six months of continuous smoking abstinence as a cut-off point for defining sustained cessation (i.e., former smokers), guided by previous relevant studies [32]. The participants were asked in 2010 to answer: "*About how long has it been since you completely quit smoking cigarettes?*"[33]. Answers equal to or higher that 26 weeks or 180 days were counted as six months or longer. Participants who responded "don't know" or refused to answer were excluded from the analysis (n=28).

In 2010, the participants were asked "*Which statement best describes the rules about smoking inside your home? No one is allowed to smoke anywhere inside your home; smoking is allowed in some places or sometimes inside your home; or smoking is*

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permitted anywhere inside your home" [33]. Those who stated that no one is allowed to smoke anywhere inside their home were classified as living in a SFH. All other respondents were classified as living in a non-SFH.

Four main NCTP were investigated in this study: cigar, regular pipes, water pipes and smokeless tobacco. Participants were asked: *"Have you ever used any of the following even one time? (The four investigated NCTP were mentioned in separate questions)*". A composite variable was created considering the use of any NCTP. Those who reported ever use of any of those products were classified as "ever users". Those "ever users" were also asked: "*Do you NOW use a "NCTP" every day, some days or not at all?".* The answers used to classify them into current and former users [33].

Statistical analysis

Prevalence of smoking relapse was estimated among the whole cohort and within each subgroup. Subgroups were compared between them using Chi-squared test.

Logistic regression models were fitted to investigate unadjusted and adjusted associations between smoking relapse and a number of factors. The dependent variable of all logistic models was smoking relapse status. The independent variables included in the final adjusted model followed a forward stepwise approach [34]. These variables were included based on literature and guided by the outcomes of the previously conducted Chi-squared tests and the univariate models. The Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) values were used to determine the final model specification. The significance level was set at 0.05. Weights were used to account for the complexity of the TUS-CPS design. The analysis

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was performed using STATA 13.1. Missing observations and those with inconsistent ever smoking status in follow-up were excluded from the analysis.

Due to the varying definitions of relapse in the literature, sensitivity analyses were conducted using different cut-off points for the duration of smoking cessation. Binary variables using one and three months as cut-off points were included into two separate models. Additionally, a separate model was fitted using four distinct periods of smoking cessation: less than 1 month, 1-3 months, 3-6 months, and 6 months or more. Reporting 30-days of abstinence was counted as one month; 13-weeks, or 90-days were counted as 3-monhts; and 26-weeks or 180-days was considered as 6-months.

Patient and Public Involvement

It was not applicable to directly involve the public in this research project as it was a secondary data analysis.

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RESULTS

Of the 18,499 participants who answered both TUS-CPS surveys in 2010 and 2011, only 3,258 met the inclusion and exclusion criteria and were considered in the final analysis. We excluded 55 participants from the analysis due to missing observations.

Table 1 illustrates the sociodemographic characteristics of the final study population based on their self-reported answers in the baseline survey. Prevalence estimates were 2.6%, 0.7%, 0.04%, and 2.5% for ever-use of cigars, regular pipes, water pipes, and smokeless tobacco products, respectively. Former users of any NCTP accounted for 37.2% among all participants.

Table 2 presents weighted prevalence of relapse among different subgroups. Out of 3,258 former smokers in 2010, a total of 184 reported smoking relapse by May 2011. They represented 6.8% (95% Confidence Interval [CI]: 5.7%-8.1%) of the cohort. Prevalence of smoking relapse was less than 20% in all subgroups, except among people aged 18-24 years (34.4%; 95%CI: 18.4%-54.9%); and among those who reported smoking abstinence for less than 6 months prior to the baseline survey (40.8%; 95%CI: 30.8%-51.6%). Within each variable, applying Chi-squared tests showed significant differences in prevalence of smoking relapse among subgroups, except by gender, education level and NCTP use.

Table 3 presents the results of the unadjusted and the final adjusted multivariable logistic regression model exploring associations of smoking relapse with individual and environmental factors among the study population. Hispanics were more likely to relapse compared to White non-Hispanics (adjusted odds ratio [aOR]: 2.05; 95% Confidence Interval [CI]: 1.03–4.08). The likelihood of relapse was also significantly associated with age. After adjusting for all the other variables, the youngest age group

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(18-24 years) still had the highest odds of relapse among all sub-groups (aOR compared to the oldest group: 15.75; 95% CI: 4.23–58.42). Gender showed no significant association with smoking relapse.

Widowed and divorced former smokers had 2.77 (95% CI: 1.31-5.84) and 2.34 (95% CI: 1.41-3.85) times the odds of relapse compared to the married group, respectively. Separated individuals had approximately four times the odds of relapse compared to married respondents (aOR: 4.16; 95%CI: 1.65-10.52). Living in a home where smoking inside was prohibited reduced the odds of relapse by 60% compared to living in homes where smoking was allowed (aOR: 0.40; 95% CI: 0.25-0.64).

Additionally, the adjusted model showed that smoking cessation for 6 months or more was a robust predictor of not relapsing, even after adjusting for the other variables. Those who reported smoking abstinence for more than 6 months had 87% lower odds of relapse compared to the group who had quit smoking for less than 6 months at the time of the 2010 survey (aOR: 0.13; 95% CI: 0.07-0.23).

The sensitivity analyses using different cut-off points for the cessation period prior to the baseline survey (Supplementary tables 1-3) consistently showed that longer periods of prior abstinence were strongly associated with lower odds of relapse.

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DISCUSSION

Our analysis estimated the overall prevalence of smoking relapse among US former smokers between 2010 and 2011 at 6.8%, although this figure varied widely among population subgroups. Five factors had significant associations with relapse: duration of smoking cessation; living in SFHs; marital status; age; and race/ethnicity.

The estimated prevalence of relapse in this study was consistent with a previous meta-analysis reporting relapse after one year of smoking abstinence which reported this figure to be between 5-17% [35]. A study comparing US and UK former smokers found that adults living in the US were more likely to relapse in less than 28 days of abstinence [36]. Americans are slightly younger in age and more ethnically and racially diverse [37], which based on the findings of our study may explain some of these differences.

We found a significant association between duration of smoking cessation and relapse, which shows that the longer it's been since quitting, the easier it gets to remain quit. This highlights that quitters may require extra support during the critical early days after stopping. This association could be primarily explained by the addictive characteristics of nicotine, the effect of which are attenuated following a relatively short period of abstinence [38]. Moreover, psychosocial, financial and cultural factors increase the risk of relapse particularly during the first 6 months of quitting [32]. another study found that three months of continuous abstinence is the critical period after which the likelihood of successful quitting increases, which is consistent with our main and sensitivity analyses [39]. However, the cessation periods calculated in this study only refer to the time prior to the first data collection point. We did not have data on the length of the abstinence period between the baseline survey and the exact time of

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relapse; hence, the actual period of abstinence may differ from what we used in our analyses.

Living in a SFH decreased the odds of relapse for former smokers by 60%. Previous studies have reported a 40% reduction in odds of relapse among similar groups [20]. A previous cohort study showed that members of households banning smoking had 12% higher likelihood to successfully quit smoking [20]. The impact of SFH on smoking behaviors is consistent among disadvantaged populations, such as low-income smokers [40], highlighting the influence of the immediate social and physical environment on smoking behaviors. Along the same lines, having a partner who is a former or current smoker may affect quitting decisions of the spouse [41]. Losing a partner may demotivate quitters from successfully maintaining smoking cessation [18 19 32]. Additionally, being separated, divorced, or widowed might drive a general feeling of insecurity and anxiety [42 43], which could explain their highest rates of relapse found in our analysis.

We also found that young adults were the most likely to relapse among all subgroups. Young adults have more opportunities to smoke in groups during parties, festivals and celebrations [44] and are more liable to peer pressure which makes them more susceptible to smoking relapse after cessation [45]. Moreover younger smokers underestimate the health consequences of smoking, which may weaken their determination to quit [19]. Older individuals in our sample were also more likely to have quit many years earlier, which, as highlighted before, is a robust predictor of sustained abstinence.

Hispanics had higher odds of relapse compared to non-Hispanic groups. Hispanics in the US are more likely to be affected by health inequalities due to health insurance

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challenges, economic burden and cultural sensitivity [46 47]. These disparities are manifested in and may be compounded by their lower success in quitting compared to Whites, which perpetuates social and health inequality in the US.

This study sheds light on smoking relapse and provides an insight into its predictors in a representative sample of the adult US population. Using a longitudinal study allowed us to explore smoking relapse over the course of twelve months. However, the TUS-CPS survey design has resulted in certain limitations. The questions were not originally designed to study smoking relapse as an independent outcome; for example, the exact time point of relapse was not reported which may have led to inaccurate estimates for some individuals; it is unclear whether any such inaccuracies may have followed a pattern that could influence the results. Relying on self-reported data and missing records placed additional challenges, as highlighted by the relatively high frequency of inconsistent reporting of ever smoker status between the two waves of the survey. As a result, although the original sample size of TUS-CPS is large, we ended up analysing a smaller subsample which reduced the precision of our estimates. Nonetheless, using weighted estimations allows us to generalise the results in the US adult population.

Our analysis contributes to the limited literature on smoking relapse. Further studies could explore the magnitude of the problem among high risk groups and in other populations as well as more factors associated with relapse. Our findings can also inform tobacco control policies and specific interventions targeting those recent quitters who are at the highest risk of relapse, especially among vulnerable groups.

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Conclusion

Smoking prevalence is a function of multiple parameters, such as initiation, cessation and relapse. Of these parameters, smoking relapse has been the least investigated. We found that age, race/ethnicity, marital status, duration of smoking cessation and living in SFHs were associated with smoking relapse among adults in the US, highlighting the need for targeted interventions to reduce relapse and increase long-term success of quit attempts.

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DECLARATION OF INTERERSTS

The authors report no conflict of interest.

AUTHORS' CONTRIBUTIONS

The first author, A.A, conducted the data analysis, reported results, and wrote the first draft of the study manuscript. The second and third authors, I.A and S.O, helped in cleaning the data and guided the analysis from their previous experience in analyzing data from the used survey. The fourth author, F.F, proposed with the first author the research question and provided support for designing and coordinating the research project, in addition to contributing in writing the final manuscript of the study. All authors significantly contributed to the research project and agreed on its all aspects.

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Table 1: Descriptive statistics of the baseline former smokers' cohort, based on the self-reported answers in the TUS-CPS 2010 survey, in the US. (N=3,258)

	N[1]	Weighted %
Sex/Gender		
Male	1639	57.3%
Female	1619	42.7%
Age group (years)		
65+	1078	31.5%
40-64	1672	48.3%
25-39	472	17.3%
18-24	36	2.9%
Race/Ethnicity		
White (non-Hispanics)	2859	83.9%
Black (non-Hispanics)	172	6.0%
Other (non-Hispanics)	101	3.6%
Hispanics	126	6.6%
Annual family income (USD)		
<20k	494	15.6%
20-49K	1110	34.8%
50-99K	1073	32.4%
100k+	581	17.3%
Education level		
<High school	356	11.8%
High school	977	29.4%
Some college[2]	1574	48.1%
College+[3]	351	10.8%
Marital status		
Married	1872	57.7%
Widowed	402	11.3%
Divorced	576	16.3%
Separated	48	1.9%
Never married	360	12.7%
Non-Cigarette Tobacco Products (NCTP) use		
Never use	1920	57.2%
Current user	159	5.6%
Former user	1144	37.2%
Smoking cessation period		
< 6 Months	127	4.8%
≥ 6 Months	3103	95.2%
Living in smoke-free home (SFH)		
Non-SFH	463	14.6%
SFH	2738	85.4%
Smoke-free workplace		
Indoor smoking-allowed	175	6.3%
Indoor smoke-free	950	31.9%
Outdoor	125	4.7%

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Undetermined	208	6.6%
Not-employed	1530	50.5%
Total	3258	100%

[1]: Number of participants. [2]: Partially completed college education. [3]: Completed a college education or higher.

- Counts and percentages in this table include only completed answers in each variable, excluding missing observations; 28 were missed in smoking cessation period, 57 in SFH, and 270 in smoke-free workplace.

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Table 2: Weighted prevalence of smoking relapse former smokers in the TUS_CPS 2010-11 cohort surveys in the US.

	N[1]	Weighted prevalence of relapse	95% CI[4]	
Overall[5] (N=3258)	**184**	**6.8%**	**5.7%**	**8.1%**
Sex/Gender				
Male	87	6.5%	5.0%	8.4%
Female	97	7.2%	5.8%	9.0%
Age group (years)				
65+	18	1.8%	1.0%	2.9%
40-64	108	6.6%	5.3%	8.1%
25-39	47	11.9%	8.8%	15.8%
18-24	11	34.4%	18.4%	54.9%
Race/Ethnicity				
White (non-Hispanics)	147	6.1%	5.0%	7.4%
Black (non-Hispanics)	14	10.0%	5.6%	17.3%
Other (non-Hispanics)	8	5.8%	2.4%	13.0%
Hispanics	15	13.7%	8.1%	22.2%
Annual family income (USD)				
<20k	40	11.5%	7.9%	16.4%
20-49K	66	7.2%	5.4%	9.5%
50-99K	52	5.2%	3.8%	7.1%
100k+	26	4.7%	3.1%	7.2%
Education level				
<High school	24	8.6%	5.5%	13.2%
High school	57	7.0%	5.1%	9.7%
Some college[2]	88	6.7%	5.3%	8.6%
College+[3]	15	4.4%	2.5%	7.8%
Marital status				
Married	82	4.7%	3.7%	5.9%
Widowed	18	4.8%	2.9%	7.9%
Divorced	43	8.4%	5.9%	11.7%
Separated	8	18.7%	9.1%	34.6%
Never married	33	14.4%	9.6%	21.0%
Non-Cigarette Tobacco Products (NCTP) use				
Never use	115	6.9%	5.7%	8.5%
Current user	12	7.4%	3.7%	14.2%
Former user	52	5.9%	4.2%	8.5%
Smoking cessation period				
< 6 Months	56	40.8%	30.8%	51.6%
≥ 6 Months	124	4.9%	4.0%	6.0%
Living in smoke-free home (SFH)				
Smoking allowed	49	13.1%	9.4%	17.9%
smoke-free home	127	5.3%	4.4%	6.5%
Smoke-free workplace				
Indoor smoking-allowed	15	9.6%	4.8%	18.3%
Indoor smoke-free	60	7.9%	5.8%	10.5%

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Outdoor	14	12.8%	7.0%	22.4%
Undetermined	13	5.8%	3.0%	10.9%
Not-employed	68	5.3%	4.0%	7.0%

[1]: Number of participants. [2]: Partially completed college education. [3]: Completed a college education or higher. [4]: Confidence Interval. [5]: Overall prevalence of relapse among all participants.

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Table 3: Predictors of smoking relapse among the US adult former smokers, data extracted from the TUS-CPS 2010-11 cohort surveys (N=3182).

Independent Variables	Unadjusted OR[2] (95% CI)	Adjusted OR[2] (95% CI)
Age group (years)		
65+ (ref)[3]	1	1
40-64	3.95 (2.23-6.99)	4.28 (2.19-8.37)
25-39	7.56 (4.05-14.10)	8.09 (3.72-17.62)
18-24	29.40 (10.89-79.37)	15.75 (4.25-58.42)
Sex/Gender		
Female (ref)[3]	1	1
Male	0.89 (0.62-1.28)	0.91 (0.61-1.37)
Smoking cessation Period		
< 6 Months (ref)[3]	1	1
≥ 6 Months	0.08 (0.05-0.12)	0.13 (0.07-0.23)
Living in SFH[4]		
Non-SFH (ref)[3]	1	1
SFH	0.37 (0.25-0.58)	0.40 (0.25-0.64)
Marital status		
Married (ref)[3]	1	1
Widowed	1.03 (0.58-1.86)	2.77 (1.31-5.84)
Divorced	1.86 (1.18-2.92)	2.34 (1.42-3.85)
Separated	4.67 (1.96-11.18)	4.16 (1.65-10.52)
Never married	3.42 (2.03-5.79)	1.48 (0.82-2.67)
Race/Ethnicity		
White (non-Hispanics) (ref)[3]	1	1
Black (non-Hispanics)	1.72 (0.88-3.36)	0.94 (0.44-2.02)
Other (non-Hispanics)	0.94 (0.38-2.36)	0.81 (0.30-2.19)
Hispanics	2.45 (1.31-4.57)	2.05 (1.03-4.08)

[1]: Confidence interval. [2]: Odds ratio. [3]: Reference group. [4]: Smoke-Free Home.

- Smoking relapse is the only outcome.

- The odds ratios in this table are all weighted.

- Adjusted odds ratio are adjusted for all variables in the table.

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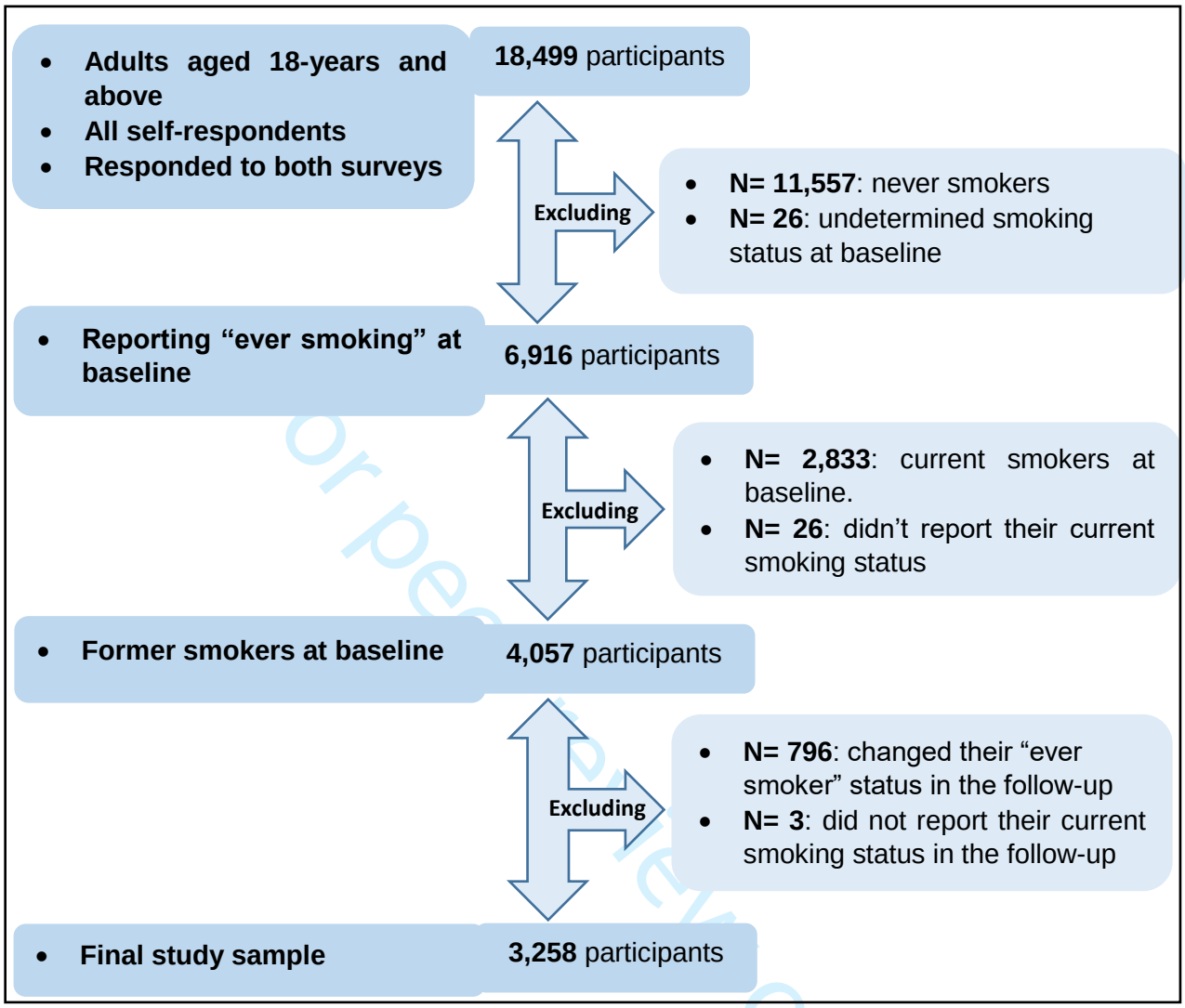

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Supplementary table-1: Results of a multivariate logistic regression model for exploring predictors of smoking relapse among the US adult smokers using 1-month as a cut-off point for stratifying the smoking cessation period.

Independent Variables	Adjusted OR[1]	95% CI[2]	
		From	To
Age group (years)			
65+ (ref)[3]	1	-	-
40-64	4.55	2.39	8.68
25-39	9.32	4.47	19.43
18-24	22.82	7.45	69.90
Sex/Gender			
Female (ref)[3]	1	-	-
Male	0.89	0.60	1.31
Smoking cessation Period*			
< 1 Month (ref)[3]	**1**	**-**	**-**
≥ 1 Month	**0.08**	**0.03**	**0.17**
Living in SFH[4]			
Non-SFH[4]	1	-	-
SFH[4]	0.44	0.28	0.69
Marital status			
Married (ref)[3]	1	-	-
Widowed	2.79	1.35	5.77
Divorced	2.34	1.45	3.78
Separated	3.89	1.49	10.16
Never married	1.62	0.96	2.74
Race/Ethnicity			
White (non-Hispanics) (ref)[3]	1	-	-
Black (non-Hispanics)	1.01	0.46	2.23
Other (non-Hispanics)	0.74	0.25	2.18
Hispanics	2.20	1.15	4.21

*[1]: Odds ratio. [2]: Confidence interval. [3]: Reference group. [4]: Smoke-Free Home. *: the variable of interest in the sensitivity analysis.*

- *Smoking relapse is the only outcome.*
- *Total number of observations considered in the model was 3,182.*
- *The odds ratios in this table are all weighted and adjusted to all included variables*
- *All the values in the table are rounded to two decimal places, except for the p-values.*

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Supplementary table-2: Results of a multivariate logistic regression model for exploring predictors of smoking relapse among the US adult smokers using 3-months as a cut-off point for stratifying the smoking cessation period.

Independent Variables	Adjusted OR[1]	95% CI[2]	
		From	To
Age group (years)			
65+ (ref)[3]	1.00	-	-
40-64	4.53	2.33	8.81
25-39	8.45	3.91	18.29
18-24	19.58	5.61	68.31
Sex/Gender			
Female (ref)[3]	1.00	-	-
Male	0.94	0.63	1.40
Smoking cessation Period*			
< 3 Months (ref)[3]	**1.00**	**-**	**-**
≥ 3 Months	**0.09**	**0.04**	**0.17**
Living in SFH[4]			
Non-SFH[4] (ref)[3]	1.00	-	-
SFH[4]	0.41	0.26	0.65
Marital status			
Married (ref)[3]	1.00	-	-
Widowed	2.77	1.32	5.79
Divorced	2.20	1.33	3.64
Separated	3.92	1.53	10.02
Never married	1.51	0.85	2.67
Race/Ethnicity			
White (non-Hispanics) (ref)[3]	1.00	-	-
Black (non-Hispanics)	0.87	0.37	2.07
Other (non-Hispanics)	0.83	0.29	2.39
Hispanics	2.06	1.06	4.01

*[1]: Odds ratio. [2]: Confidence interval. [3]: Reference group. [4]: Smoke-Free Home. *: the variable of interest in the sensitivity analysis.*

- *Smoking relapse is the only outcome.*
- *Total number of observations considered in the model was 3,182.*
- *The odds ratios in this table are all weighted and adjusted to all included variables*
- *All the values in the table are rounded to two decimal places, except for the p-values.*

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Supplementary table-3: Results of a multivariate logistic regression model for exploring predictors of smoking relapse among the US adult smokers using 1, 3 and 6-months as cut-off points for stratifying the smoking cessation period.

Independent Variables	Adjusted OR[1]	95% CI[2]	
		From	To
Age group (years)			
65+ (ref)[3]	1.00	-	-
40-64	4.40	2.25	8.61
25-39	8.20	3.76	17.89
18-24	16.96	4.64	62.01
Sex/Gender			
Female (ref)[3]	1.00	-	-
Male	0.94	0.62	1.41
Smoking cessation Period*			
< 1 Month (ref)[3]	**1.00**	**-**	**-**
1 - 3 Months	**0.61**	**0.18**	**2.03**
3 - 6 Months	**0.21**	**0.06**	**0.74**
≥ 6 Months	**0.06**	**0.03**	**0.14**
Living in SFH[4]			
Non-SFH[4] (ref)[3]	1.00	-	-
SFH[4]	0.41	0.26	0.65
Marital status			
Married (ref)[3]	1.00	-	-
Widowed	2.80	1.33	5.91
Divorced	2.29	1.38	3.79
Separated	3.94	1.52	10.21
Never married	1.47	0.81	2.65
Race/Ethnicity			
White (non-Hispanics) (ref)[3]	1.00	-	-
Black (non-Hispanics)	0.88	0.38	2.06
Other (non-Hispanics)	0.84	0.30	2.37
Hispanics	2.02	1.02	3.99

*[1]: Odds ratio. [2]: Confidence interval. [3]: Reference group. [4]: Smoke-Free Home. *: the variable of interest in the sensitivity analysis.*

- *Smoking relapse is the only outcome.*
- *Total number of observations considered in the model was 3,182.*
- *The odds ratios in this table are all weighted and adjusted to all included variables*
- *All the values in the table are rounded to two decimal places, except for the p-values.*

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Prevalence and determinants of cigarette smoking relapse among US adult smokers - a longitudinal study

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ABSTRACT

Objectives: This research project aims at estimating the prevalence of cigarette smoking relapse and determining its predictors among adult former smokers in the United States (US).

Setting: This research analysed secondary data retrieved from the Tobacco Use Supplement-Current Population Survey (TUS-CPS) 2010-11 cohort in the US.

Participants: Out of 18,499 participants who responded to the survey in 2010 and 2011, the analysis included a total sample size of 3,258 ever smokers, who were living in the US and reported quitting smoking in 2010. The survey's respondents who never smoked or reported current smoking in 2010 were excluded from the study sample.

Primary and secondary outcome measures: Smoking relapse was defined as picking up smoking in 2011 after reporting smoking abstinence in 2010. The prevalence of relapse over the 12-month follow-up period was estimated among different subgroups. Multivariable logistic regression models were applied to determine factors associated with relapse.

Results: A total of 184 former smokers reported smoking relapse by 2011 (weighted prevalence: 6.8%; 95% Confidence Interval [CI]: 5.7%-8.1%). Prevalence and odds of relapse were higher among young people compared to elders. Former smokers living in smoke-free homes had 60% lower odds of relapse compared to those living in homes that allowed smoking inside (aOR: 0.40; 95%CI: 0.25-0.64). Regarding race/ethnicity, only Hispanics showed significantly higher odds of relapse compared to Whites (non-Hispanics). Odds of relapse were higher among never married, widowed, divorced and separated individuals, compared to the married group. Continuous smoking cessation for 6 months or more significantly decreased odds of relapse.

Conclusions: Wider health determinants, such as race and age, but also living in smoke-free homes showed significant associations with smoking relapse, which could inform the

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development of more targeted programmes to support those smokers who successfully quit, although further longitudinal studies are required to confirm our findings.

ARTICLE SUMMARY

Strengths and limitations of this study

- The data was retrieved from a longitudinal study, which is suitable for studying smoking relapse as a behaviour that develops over time after cessation.
- We used data from the most recent longitudinal survey of the TUS-CPS (2010-11) which is relatively old.
- Results should be interpreted with caution due to the relatively small sample size in some subgroups.
- Some factors found to be associated with relapse in earlier studies were not available in the dataset to be included in the regression models.
- Due to the inconsistent definitions of smoking relapse in the literature, sensitivity analyses were conducted using different cut-off points for the duration of smoking cessation.

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LIST OF ABBREVIATIONS

AIC	Akaike information criterion
aOR	Adjusted Odds Ratio
BIC	Bayesian information criterion
CDC	Centres of Disease Control and Prevention
CHD	Coronary Heart Disease
CI	Confidence Interval
COPD	Chronic Obstructive Pulmonary Diseases
CPS	Current Population Survey
CVD	Cardiovascular Diseases
D.C	District of Columbia
FCTC	WHO Framework Convention on Tobacco Control
GDP	Gross Domestic Product
HP2020	Healthy People 2020
N	Number of observations
NCTP	Non-Cigarette Tobacco Products
OR	Unadjusted Odds Ratio
RR	Relative Risk
SFH	Smoke Free Home
TUS	Tobacco Use Supplement
TUS-CPS	Tobacco Use Supplement-Current Population Survey
UK	United Kingdom
US	United States of America
WHO	World Health Organisation

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INTRODUCTION

The World Health Organisation (WHO) estimates that there are 1.1 billion current smokers worldwide (1). According to the Centres for Disease Control and Prevention (CDC), 37.8 million adults were active smokers in the United States (US) in 2016, representing more than 15.5% of the total US population (2). Annually, smoking leads to 480,000 deaths in the US (3), and its related hazards cost approximately 1% of the country's Gross Domestic Product (GDP) (4, 5).

The prevalence of smoking is determined by the proportion of the non-smoking population that initiates smoking, and the proportion of smokers who die or quit. Most tobacco control programs aim to reduce smoking prevalence by preventing smoking initiation and promoting cessation; however, long-term cessation remains challenging. Although research on smoking cessation is abundant, most studies have explored factors associated with quit intentions and overall determinants of smoking abstinence (6-8), with only a few focusing on "relapsing"; i.e. restarting smoking after a temporarily successful cessation attempt.

Despite variations in the definitions used in the literature, smoking relapse essentially means picking up smoking after a period of abstinence (9). In past research, relapse rates within the first year of abstinence ranged from 60% to 90%, while two years of continuous cessation indicated a likelihood of 80% to maintain long-term abstinence (10). In this study, we use cigarette smoking to define relapse, as it is the most common method of tobacco use in the US and globally (>90%) (9). Thus, "smoking" refers to "cigarette smoking".

Although relapse has rarely been the specific focus of smoking cessation research, it is reasonable to assume that at least some of the factors found to be associated with smoking cessation overall also play a role in the process of relapse. Previous studies have reported a link between genetic factors and smoking behaviours (11). Other personal characteristics have been highlighted in relevant studies, including age (12), sex (13), race/ethnicity (14), and nicotine dependence (15). Researchers have previously shown that knowledge and

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perceptions of smoking hazards influence individual intentions and motivations to quit or relapse (16, 17). Recent studies indicated the influence of community factors and support given to smokers on their determination and willingness to quit (18, 19). There is also evidence with regard to the impact of living in a Smoke-Free Home (SFH) (20), using Non-Cigarette Tobacco Products (NCTP) (21-23) and seeking specialist advice for quitting on smoking behaviours (24). Additionally, research showed that smokers newly diagnosed with chronic diseases, such as obstructive lung diseases, were more likely to quit smoking (25, 26).

Nevertheless, there is a scarcity of studies assessing determinants of smoking relapse in particular, which remains an under-researched area. To fill this gap, this study aimed to measure the prevalence of cigarette smoking relapse among adult former smokers in the US and to determine predictors of relapse using a nationally representative longitudinal sample.

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METHODS

Data Source

We conducted a secondary analysis of longitudinal data retrieved from the Tobacco Use Supplement-Current Population Survey (TUS-CPS). This survey has been conducted every 3 to 4 years in the US since 1992. It collects a broad range of data about the US population with topics varying from year to year. For this study, we used a longitudinal sample of the survey; the cohort baseline data was collected in May 2010 and the follow-up survey was conducted in May 2011. It focused on the population's smoking behaviours and cessation attitudes. No other data was recorded between these two time points (27, 28).

Selection of TUS-CPS respondents is designed to yield representative estimates for the US overall, as well as the 50 states and Washington, D.C. (29, 30). Since 2006, the survey has targeted US adults aged 18 years and above (28, 29). The cohort of 2010-11 was the most recent longitudinal sample of the survey that assessed the outcome of interest, smoking relapse. Data was collected by telephone or in-person interviews (29). In this particular cohort, 64% of participants completed the survey through telephone interviews and 36% through in-person interviews (27, 29). Approximately 20% of the data was recorded by proxy, while the rest was self-reported (29). For this research project, we only used data collected from self-respondents.

The analysis sample comprised individuals who reported being former smokers at baseline (May 2010 survey wave). Their smoking status was self-reported again after one year (May 2011). Relapse was defined as a failure to maintain smoking cessation between the two time points of data collection in the TUS-CPS surveys. Those who didn't report their smoking status in either wave or provided inconsistent data regarding having ever smoked between the two waves were excluded from the analysis. After applying the inclusion and exclusion criteria, the final study sample was 3,258, as illustrated in Figure 1.

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Measures

Cigarette smoking relapse status is the principle outcome of this study. Participants were asked to report their smoking status in 2010 and 2011; "*Do you now smoke cigarettes every day, some days, or not at all?*" Responses were categorized into a dichotomous variable (yes [every day or some days], and no [not at all]). Those who responded "not at all" in 2010, but "every day" or "some days" in 2011 were considered to have relapsed. Daily and non-daily smokers were grouped together as it has been shown that even very low cigarette consumption is associated with significant health risks (31).

Sociodemographic variables included age (18-24, 25-39, 40-65 and ≥65 years); sex (male, female); race/ethnicity (Hispanics, White non-Hispanics, Black non-Hispanics, and other non-Hispanics); education level, determined by the highest accomplished level (<high school, high school, some college, defined as partially completed college education, and college or higher); and finally, socioeconomic status, reflected by annual family income (US$ <20k, 20-49k, 50-99k and ≥100k). Categorising these variables was based on previously published reports and studies using the TUS-CPS surveys (32).

This study used six months of continuous smoking abstinence as a cut-off point for defining sustained cessation (i.e., former smokers), guided by previous relevant studies (33). The participants were asked in 2010 to answer: "*About how long has it been since you completely quit smoking cigarettes?*"(34). Answers equal to or higher that 26 weeks or 180 days were counted as six months or longer. Participants who responded "don't know" or refused to answer were excluded from the analysis (n=28).

In 2010, the participants were asked "*Which statement best describes the rules about smoking inside your home? No one is allowed to smoke anywhere inside your home; smoking is allowed in some places or sometimes inside your home; or smoking is permitted anywhere inside your home*" (34). Those who stated that no one is allowed to smoke anywhere inside their home were classified as living in a SFH. All other respondents were classified as living in a non-SFH.

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Use of four NCTPs were investigated in this study as factors potentially associated with cigarette smoking relapse: cigar, regular pipes, water pipes and smokeless tobacco. Participants were asked: *"Have you ever used any of the following even one time? (The four investigated NCTP were mentioned in separate questions)*". A composite variable was created considering the use of any NCTP. Those who reported ever use of any of those products were classified as "ever users". Those "ever users" were also asked: "*Do you NOW use a "NCTP" every day, some days or not at all?".* The answers used to classify them into current and former users (34).

Statistical analysis

Prevalence of smoking relapse was estimated among the whole cohort and within each subgroup. Logistic regression models were fitted to investigate unadjusted and adjusted associations between smoking relapse and a set of factors. The dependent variable of all logistic regression models was smoking relapse status. Factors identified as potentially relevant in existing literature were considered for inclusion in the models. The final specification of the models was decided based on an iterative approach using the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). The significance level was set at 0.05. The official weights provided in the original datasets were used to account for the complexity of the TUS-CPS design. The analysis was performed using STATA 13.1. Missing observations and those with inconsistent ever smoking status in the follow-up survey were excluded from the analysis.

Due to the varied definitions of smoking relapse in the literature, sensitivity analyses were conducted using different cut-off points for the duration of smoking cessation. Binary variables using one and three months as cut-off points were included into two separate models. Additionally, a separate model was fitted using four distinct periods of smoking cessation: less than 1 month, 1-3 months, 3-6 months, and 6 months or more. Reporting 30-days of

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abstinence was counted as one month; 13-weeks, or 90-days were counted as 3-months; and 26-weeks or 180-days was considered as 6-months.

Patient and Public Involvement

It was not applicable to directly involve the public in this research project as it was a secondary data analysis. Ethics approval and consents were deemed unnecessary for this study under national regulations.

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RESULTS

After applying the inclusion and exclusion criteria only 3,258 of the 18,499 participants who answered both TUS-CPS surveys in 2010 and 2011 were included in the final analysis. We excluded 55 participants from the analysis due to missing observations.

Table 1 illustrates the sociodemographic characteristics of the final study population based on their self-reported answers in the baseline survey. Prevalence estimates were 2.6%, 0.7%, 0.04%, and 2.5% for ever-use of cigars, regular pipes, water pipes, and smokeless tobacco products, respectively. Former users of any NCTP accounted for 37.2% among all participants.

Figure 2 presents weighted prevalence of relapse among different subgroups. Out of 3,258 former smokers in 2010, a total of 184 reported smoking relapse by May 2011. They represented 6.8% (95% Confidence Interval [CI]: 5.7%-8.1%) of the cohort. The prevalence of smoking relapse was lower than 20% in all subgroups, except among people aged 18-24 years (34.4%; 95% CI: 18.4%-54.9%); and among those who reported smoking abstinence for less than 6 months prior to the baseline survey (40.8%; 95%CI: 30.8%-51.6%).

Table 2 presents the results of the unadjusted and the final adjusted multivariable logistic regression model exploring associations of smoking relapse with individual and environmental factors among the study population. Despite the limited number of Hispanic participants, they were more likely to relapse compared to White non-Hispanics (adjusted odds ratio [aOR]: 2.05; 95% CI: 1.03–4.08). The likelihood of relapse was also significantly associated with age. After adjusting for all the other variables, the youngest age group (18-24 years) still had the highest odds of relapse among all sub-groups (aOR compared to the oldest group: 15.75; 95% CI: 4.23–58.42). Sex showed no significant association with smoking relapse, although there is some suggestion that males were less likely to relapse.

Widowed and divorced former smokers had 2.77 (95% CI: 1.31-5.84) and 2.34 (95% CI: 1.41-3.85) times the odds of relapse compared to the married group, respectively. Separated

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individuals had approximately four times the odds of relapse compared to married respondents (aOR: 4.16; 95% CI: 1.65-10.52). Living in a home where smoking inside was prohibited reduced the odds of relapse by 60% compared to living in homes where smoking was allowed (aOR: 0.40; 95% CI: 0.25-0.64).

Additionally, the adjusted model showed that smoking cessation for 6 months or more was a robust predictor of not relapsing, even after adjusting for the other variables. Those who reported smoking abstinence for more than 6 months had 87% lower odds of relapse compared to the group who had quit smoking for less than 6 months at the time of the 2010 survey (aOR: 0.13; 95% CI: 0.07-0.23).

The sensitivity analyses using different cut-off points for the cessation period prior to the baseline survey (Supplementary tables 1-3) consistently showed that longer periods of prior abstinence were strongly associated with lower odds of relapse.

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DISCUSSION

Our analysis estimated the overall prevalence of smoking relapse among US former smokers between 2010 and 2011 at 6.8%, although this figure varied widely among population subgroups. Five factors had significant associations with relapse: duration of smoking cessation; living in SFHs; marital status; age; and race/ethnicity.

The estimated prevalence of relapse in this study was consistent with a previous meta-analysis reporting relapse after one year of smoking abstinence which reported this figure to be between 5-17% (35). A study comparing US and UK former smokers found that adults living in the US were more likely to relapse in less than 28 days of abstinence (36). Americans are slightly younger in age and more ethnically and racially diverse (37), which based on the findings of our study may explain some of these differences.

We found a significant association between duration of smoking cessation and relapse, which shows that the longer it's been since quitting, the easier it gets to remain quit. This highlights that quitters may require extra support during the critical early days after stopping. This association could be primarily explained by the addictive characteristics of nicotine, the effect of which are attenuated following a relatively short period of abstinence (38). Moreover, psychosocial, financial and cultural factors increase the risk of relapse particularly during the first 6 months of quitting (33). Another study found that three months of continuous abstinence is the critical period after which the likelihood of successful quitting increases, which is consistent with our main and sensitivity analyses (39). However, the cessation periods calculated in this study only refer to the time prior to the first data collection point. We did not have data on the length of the abstinence period between the baseline survey and the exact time of relapse; hence, the actual period of abstinence may differ from what we used in our analyses, although we have no reason to believe this may have introduced systematic error in our analysis.

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Living in a SFH decreased the odds of relapse for former smokers by 60%. Previous studies have reported a 40% reduction in odds of relapse among similar groups (20). A previous cohort study showed that members of households banning smoking had 12% higher likelihood to successfully quit smoking (20). The impact of SFH on smoking behaviours is consistent among disadvantaged populations, such as low-income smokers (40), highlighting the influence of the immediate social and physical environment on smoking behaviours. Along the same lines, having a partner who is a former or current smoker may affect quitting decisions of the spouse (41). Losing a partner may demotivate quitters from successfully maintaining smoking cessation (16, 17, 33). Additionally, being separated, divorced, or widowed might drive a general feeling of insecurity and anxiety (42, 43), which could explain the higher rates of relapse found among these subgroups in our analysis.

We also found that young adults were the most likely to relapse among all subgroups. Young adults have more opportunities to smoke in groups during parties, festivals and celebrations (44) and are more vulnerable to peer pressure which makes them more susceptible to smoking relapse after cessation (45). Younger smokers may also underestimate the health consequences of smoking, which may weaken their determination to quit (17). Older individuals in our sample were also more likely to have quit many years earlier, which, as highlighted before, is a robust predictor of sustained abstinence.

Hispanics had higher odds of relapse compared to non-Hispanic groups. Hispanics in the US are more likely to be affected by health inequalities due to health insurance challenges, economic burden and cultural sensitivity (46, 47). These disparities are manifested in and may be compounded by their lower success in quitting compared to Whites, which perpetuates social and health inequality in the US.

This study sheds light on smoking relapse and provides an insight into its predictors in a representative sample of the adult US population. Using a longitudinal design allowed us to explore smoking relapse over the course of twelve months. However, the tobacco products

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environment has changed considerably since 2011; therefore, our findings may not fully reflect the current conditions in the US.

The questions of TUS-CPS were not originally designed to study smoking relapse as an outcome; for example, the exact time point of relapse was not reported which may have led to inaccurate estimates for some individuals; it is unclear whether any such inaccuracies may have followed a pattern that could influence the results. The scope of the study was also not broad enough to investigate some factors shown to have significant associations with smoking relapse in previous studies, such as genetic factors (11) and perceptions regarding smoking hazards (16, 17).

Relying only on self-reported data and the relatively high frequency of inconsistent reporting of ever smoker status between the two waves of the survey may have introduced selection bias which would have an impact on the representativeness of the study sample. Moreover, although the original sample size of TUS-CPS was large, our analytical sample was smaller; hence findings in certain subgroups, such as the Hispanics, should be interpreted with caution. Nonetheless, the overall sample was originally weighted in the main dataset to be representative of the national population.

Our analysis contributes to the limited literature on the epidemiology of smoking relapse at the population level. Further studies could explore the magnitude of the problem among high risk groups and in other populations as well as more factors associated with relapse. Our findings can also inform tobacco control policies and specific interventions targeting those recent quitters who are at the highest risk of relapse, especially among vulnerable groups.

Conclusion

Smoking prevalence is a function of multiple parameters, such as initiation, cessation and relapse. Of these parameters, smoking relapse has been the least investigated. The prevalence of relapse within a one-year period was estimated at 6.8% in this study. We found

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that age, race/ethnicity, marital status, duration of smoking cessation and living in SFHs were associated with smoking relapse among adults in the US, highlighting the need for targeted interventions to reduce relapse and increase long-term success of quit attempts. Further research purposefully designed to monitor and investigate relapse should be directed to explore determinants of relapse among different populations, and at various points in time following cessation.

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DECLARATION OF INTERERSTS

The authors report no conflict of interest.

DATA AVAILABILITY STATEMENT

The data is publically available on the website of the Centers for Disease Control and Prevention (CDC), USA. It can be accessed and downloaded through the page of "Tobacco Use Supplement to the Current Population Survey (TUS-CPS) Data" on the website; https://healthdata.gov/dataset/tobacco-use-supplement-current-population-survey-tus-cps-data. No unpublished data were used in the study.

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AUTHORS' CONTRIBUTIONS

The first author, A.A, conducted the data analysis, reported results, and wrote the first draft of the study manuscript. The second and third authors, I.A and S.O, helped in cleaning the data and guided the analysis from their previous experience in analyzing data from the used survey. The fourth author, F.F, proposed with the first author the research question and provided support for designing and coordinating the research project, in addition to contributing in writing the final manuscript of the study. All authors significantly contributed to the research project and agreed on its all aspects.

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Table 1: Descriptive statistics of the baseline former smokers' cohort, based on the self-reported answers in the TUS-CPS 2010 survey, in the US. (N=3,258)

	N[1]	Weighted %[2]
Sex		
Male	1639	57.3%
Female	1619	42.7%
Age group (years)		
65+	1078	31.5%
40-64	1672	48.3%
25-39	472	17.3%
18-24	36	2.9%
Race/Ethnicity		
White (non-Hispanics)	2859	83.9%
Black (non-Hispanics)	172	6.0%
Other (non-Hispanics)	101	3.6%
Hispanics	126	6.6%
Annual family income (USD)		
<20k	494	15.6%
20-49K	1110	34.8%
50-99K	1073	32.4%
100k+	581	17.3%
Education level		
<High school	356	11.8%
High school	977	29.4%
Some college[3]	1574	48.1%
College+[4]	351	10.8%
Marital status		
Married	1872	57.7%
Widowed	402	11.3%
Divorced	576	16.3%
Separated	48	1.9%
Never married	360	12.7%
Non-Cigarette Tobacco Products (NCTP) use		
Never use	1920	57.2%
Current user	159	5.6%
Former user	1144	37.2%
Smoking cessation period		
< 6 Months	127	4.8%
≥ 6 Months	3103	95.2%
Living in smoke-free home (SFH)		
Non-SFH	463	14.6%
SFH	2738	85.4%
Smoke-free workplace		
Indoor smoking-allowed	175	6.3%
Indoor smoke-free	950	31.9%
Outdoor	125	4.7%

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Undetermined	208	6.6%
Not-employed	1530	50.5%
Total	3258	100%

[1]: Number of participants. [2]:Using official weights to ensure the sample is representative of the source population[3]: Partially completed college education. [4]: Completed a college education or higher.

- Counts and percentages in this table include only completed answers in each variable, excluding missing observations; 28 were missed in smoking cessation period, 57 in SFH, and 270 in smoke-free workplace.

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Table 2: Predictors of smoking relapse among the US adult former smokers, data extracted from the TUS-CPS 2010-11 cohort surveys (N=3182).

Independent Variables	Unadjusted OR[2] (Lower and Upper Limits of 95% CI)	Adjusted OR[2] (Lower and Upper Limits of 95% CI)
Age group (years)		
65+ (ref)[3]	1	1
40-64	3.95 (2.23-6.99)	4.28 (2.19-8.37)
25-39	7.56 (4.05-14.10)	8.09 (3.72-17.62)
18-24	29.40 (10.89-79.37)	15.75 (4.25-58.42)
Sex		
Female (ref)[3]	1	1
Male	0.89 (0.62-1.28)	0.91 (0.61-1.37)
Smoking cessation Period		
< 6 Months (ref)[3]	1	1
≥ 6 Months	0.08 (0.05-0.12)	0.13 (0.07-0.23)
Living in SFH[4]		
Non-SFH (ref)[3]	1	1
SFH	0.37 (0.25-0.58)	0.40 (0.25-0.64)
Marital status		
Married (ref)[3]	1	1
Widowed	1.03 (0.58-1.86)	2.77 (1.31-5.84)
Divorced	1.86 (1.18-2.92)	2.34 (1.42-3.85)
Separated	4.67 (1.96-11.18)	4.16 (1.65-10.52)
Never married	3.42 (2.03-5.79)	1.48 (0.82-2.67)
Race/Ethnicity		
White (non-Hispanics) (ref)[3]	1	1
Black (non-Hispanics)	1.72 (0.88-3.36)	0.94 (0.44-2.02)
Other (non-Hispanics)	0.94 (0.38-2.36)	0.81 (0.30-2.19)
Hispanics	2.45 (1.31-4.57)	2.05 (1.03-4.08)

[1]: Confidence interval. [2]: Odds ratio. [3]: Reference group. [4]: Smoke-Free Home.

- Smoking relapse is the only outcome.

- The odds ratios in this table are all weighted.

- Adjusted odds ratio are adjusted for all variables in the table.

- AIC Value: 1134.57; BIC Value: 1219.49

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Figure 1: flow chart illustrates the steps of selecting the study sample based on the inclusion and exclusion criteria

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Figure 2. Weighted prevalence of smoking relapse former smokers in the TUS_CPS 2010-11 cohort surveys in the US (N=3258)

Some college: Partially completed college education. College+: Completed a college education or higher. CI: Confidence Interval. OVERALL: Overall prevalence of relapse among all participants. NCTP: Non-cigarette tobacco products. Weighted prevalence has incorporated official weights to ensure the sample is representative of the source population.

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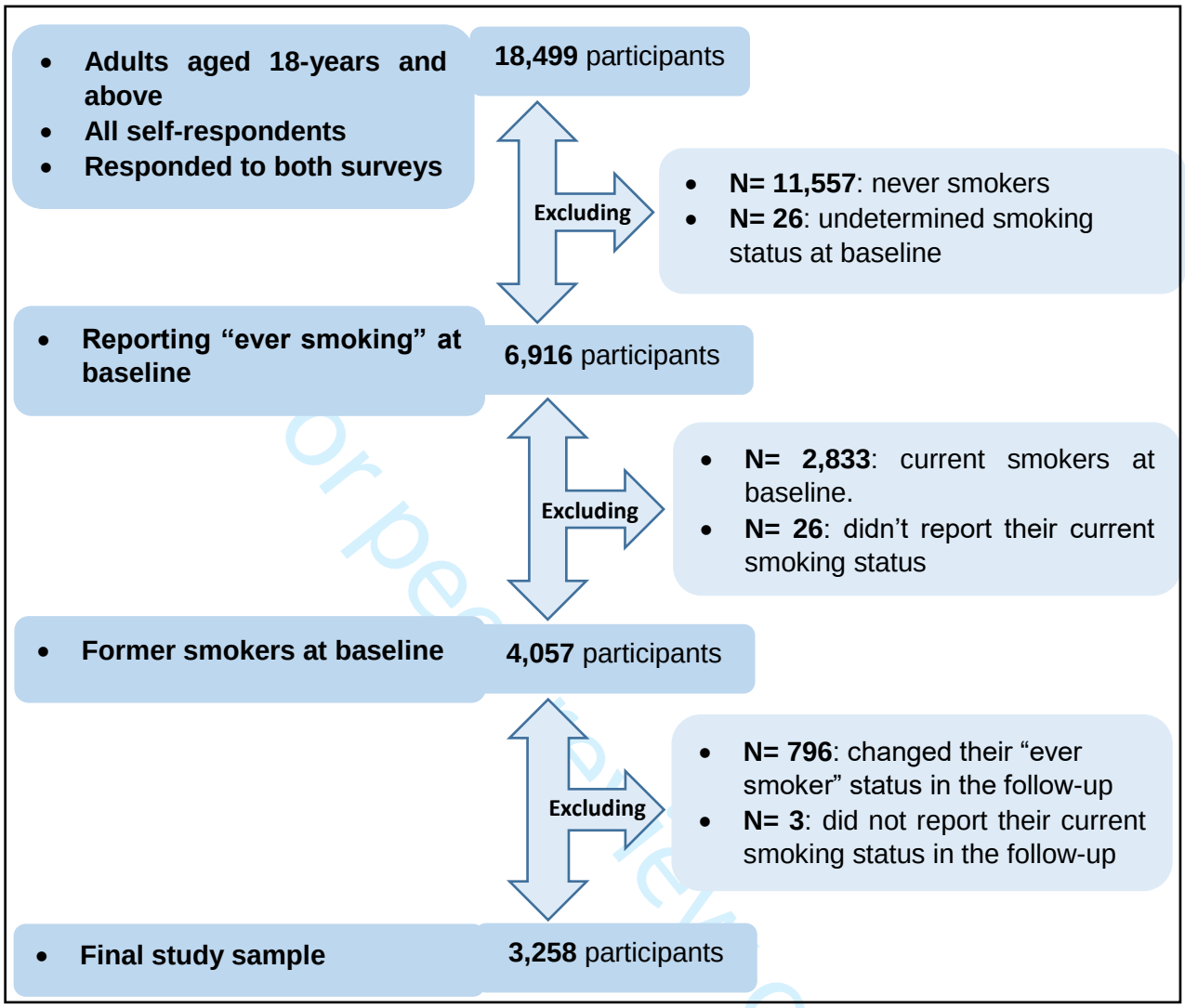

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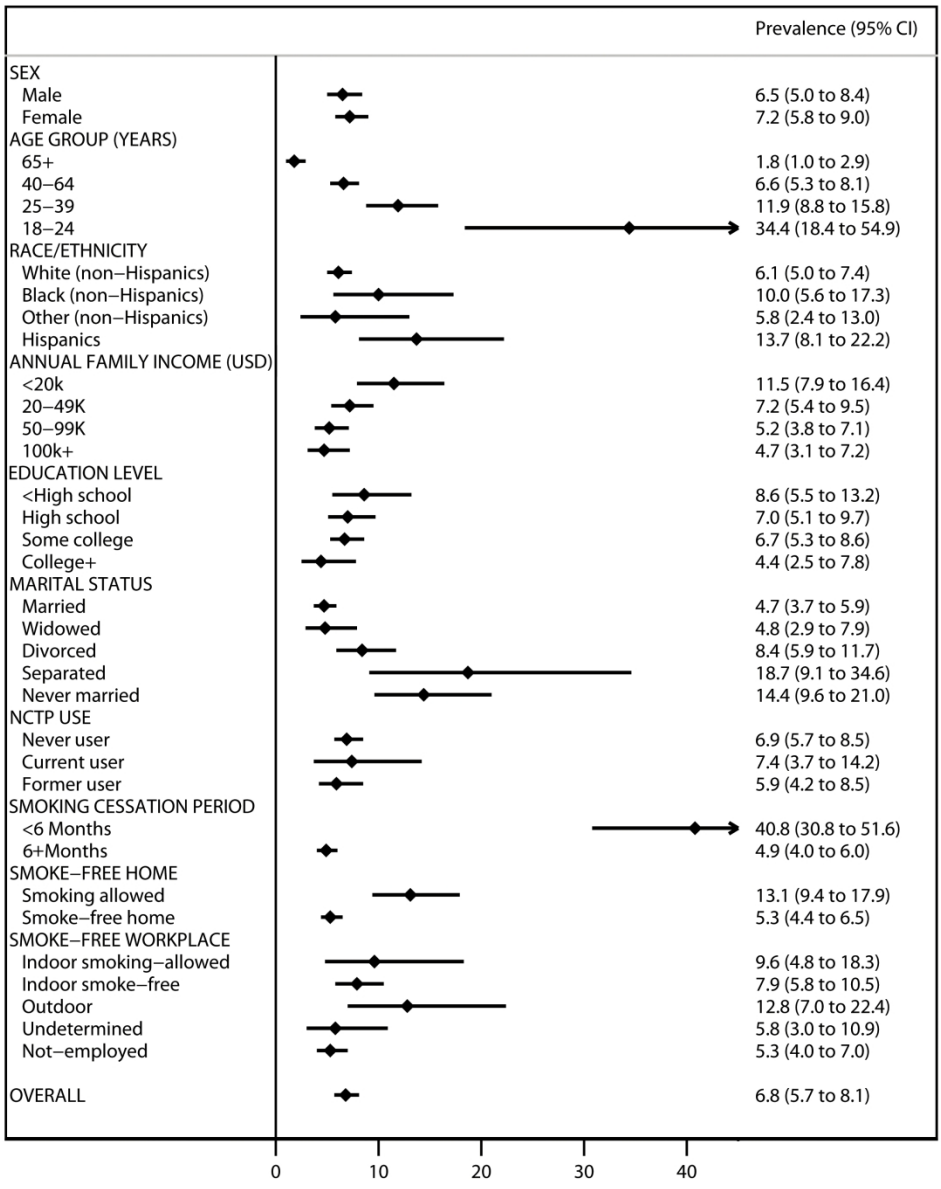

Figure 2. Weighted prevalence of smoking relapse former smokers in the TUS_CPS 2010-11 cohort surveys in the US (N=3258)

Some college: Partially completed college education. College+: Completed a college education or higher. CI: Confidence Interval. OVERALL: Overall prevalence of relapse among all participants. NCTP: Non-cigarette tobacco products. Weighted prevalence has incorporated official weights to ensure the sample is representative of the source population.

229x286mm (300 x 300 DPI)

Supplementary table-1: Results of a multivariate logistic regression model for exploring predictors of smoking relapse among the US adult smokers using 1-month as a cut-off point for stratifying the smoking cessation period.

Independent Variables	Adjusted OR[1]	Lower and upper limits of 95% CI[2]	
		Lower	Upper
Age group (years)			
65+ (ref)[3]	1	-	-
40-64	4.55	2.39	8.68
25-39	9.32	4.47	19.43
18-24	22.82	7.45	69.90
Sex/Gender			
Female (ref)[3]	1	-	-
Male	0.89	0.60	1.31
Smoking cessation Period*			
< 1 Month (ref)[3]	**1**	**-**	**-**
≥ 1 Month	**0.08**	**0.03**	**0.17**
Living in SFH[4]			
Non-SFH[4]	1	-	-
SFH[4]	0.44	0.28	0.69
Marital status			
Married (ref)[3]	1	-	-
Widowed	2.79	1.35	5.77
Divorced	2.34	1.45	3.78
Separated	3.89	1.49	10.16
Never married	1.62	0.96	2.74
Race/Ethnicity			
White (non-Hispanics) (ref)[3]	1	-	-
Black (non-Hispanics)	1.01	0.46	2.23
Other (non-Hispanics)	0.74	0.25	2.18
Hispanics	2.20	1.15	4.21

*[1]: Odds ratio. [2]: Confidence interval. [3]: Reference group. [4]: Smoke-Free Home. *: the variable of interest in the sensitivity analysis.*

- *Smoking relapse is the only outcome.*
- *Total number of observations considered in the model was 3,182.*
- *The odds ratios in this table are all weighted and adjusted to all included variables*
- *All the values in the table are rounded to two decimal places, except for the p-values.*

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Supplementary table-2: Results of a multivariate logistic regression model for exploring predictors of smoking relapse among the US adult smokers using 3-months as a cut-off point for stratifying the smoking cessation period.

Independent Variables	Adjusted OR[1]	Lower and upper limits of 95% CI[2]	
		Lower	Upper
Age group (years)			
65+ (ref)[3]	1.00	-	-
40-64	4.53	2.33	8.81
25-39	8.45	3.91	18.29
18-24	19.58	5.61	68.31
Sex/Gender			
Female (ref)[3]	1.00	-	-
Male	0.94	0.63	1.40
Smoking cessation Period*			
< 3 Months (ref)[3]	**1.00**	**-**	**-**
≥ 3 Months	**0.09**	**0.04**	**0.17**
Living in SFH[4]			
Non-SFH[4] (ref)[3]	1.00	-	-
SFH[4]	0.41	0.26	0.65
Marital status			
Married (ref)[3]	1.00	-	-
Widowed	2.77	1.32	5.79
Divorced	2.20	1.33	3.64
Separated	3.92	1.53	10.02
Never married	1.51	0.85	2.67
Race/Ethnicity			
White (non-Hispanics) (ref)[3]	1.00	-	-
Black (non-Hispanics)	0.87	0.37	2.07
Other (non-Hispanics)	0.83	0.29	2.39
Hispanics	2.06	1.06	4.01

*[1]: Odds ratio. [2]: Confidence interval. [3]: Reference group. [4]: Smoke-Free Home. *: the variable of interest in the sensitivity analysis.*

- *Smoking relapse is the only outcome.*
- *Total number of observations considered in the model was 3,182.*
- *The odds ratios in this table are all weighted and adjusted to all included variables*
- *All the values in the table are rounded to two decimal places, except for the p-values.*

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Supplementary table-3: Results of a multivariate logistic regression model for exploring predictors of smoking relapse among the US adult smokers using 1, 3 and 6-months as cut-off points for stratifying the smoking cessation period.

Independent Variables	Adjusted OR[1]	Lower and upper limits of 95% CI[2]	
		Lower	Upper
Age group (years)			
65+ (ref)[3]	1.00	-	-
40-64	4.40	2.25	8.61
25-39	8.20	3.76	17.89
18-24	16.96	4.64	62.01
Sex/Gender			
Female (ref)[3]	1.00	-	-
Male	0.94	0.62	1.41
Smoking cessation Period*			
< 1 Month (ref)[3]	**1.00**	**-**	**-**
1 - 3 Months	**0.61**	**0.18**	**2.03**
3 - 6 Months	**0.21**	**0.06**	**0.74**
≥ 6 Months	**0.06**	**0.03**	**0.14**
Living in SFH[4]			
Non-SFH[4] (ref)[3]	1.00	-	-
SFH[4]	0.41	0.26	0.65
Marital status			
Married (ref)[3]	1.00	-	-
Widowed	2.80	1.33	5.91
Divorced	2.29	1.38	3.79
Separated	3.94	1.52	10.21
Never married	1.47	0.81	2.65
Race/Ethnicity			
White (non-Hispanics) (ref)[3]	1.00	-	-
Black (non-Hispanics)	0.88	0.38	2.06
Other (non-Hispanics)	0.84	0.30	2.37
Hispanics	2.02	1.02	3.99

*[1]: Odds ratio. [2]: Confidence interval. [3]: Reference group. [4]: Smoke-Free Home. *: the variable of interest in the sensitivity analysis.*

- *Smoking relapse is the only outcome.*
- *Total number of observations considered in the model was 3,182.*
- *The odds ratios in this table are all weighted and adjusted to all included variables*
- *All the values in the table are rounded to two decimal places, except for the p-values.*

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The RECORD statement – checklist of items, extended from the STROBE statement, that should be reported in observational studies using routinely collected health data.

	Item No.	STROBE items	Location in manuscript where items are reported	RECORD items	Location in manuscript where items are reported
Title and abstract					
	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found	0-1	RECORD 1.1: The type of data used should be specified in the title or abstract. When possible, the name of the databases used should be included. RECORD 1.2: If applicable, the geographic region and timeframe within which the study took place should be reported in the title or abstract. RECORD 1.3: If linkage between databases was conducted for the study, this should be clearly stated in the title or abstract.	1
Introduction					
Background rationale	2	Explain the scientific background and rationale for the investigation being reported	5		
Objectives	3	State specific objectives, including any prespecified hypotheses	6		
Methods					
Study Design	4	Present key elements of study design early in the paper	7		
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7		

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Participants	6	*(a) Cohort study* - Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study* - Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study* - Give the eligibility criteria, and the sources and methods of selection of participants *(b) Cohort study* - For matched studies, give matching criteria and number of exposed and unexposed *Case-control study* - For matched studies, give matching criteria and the number of controls per case	7	RECORD 6.1: The methods of study population selection (such as codes or algorithms used to identify subjects) should be listed in detail. If this is not possible, an explanation should be provided. RECORD 6.2: Any validation studies of the codes or algorithms used to select the population should be referenced. If validation was conducted for this study and not published elsewhere, detailed methods and results should be provided. RECORD 6.3: If the study involved linkage of databases, consider use of a flow diagram or other graphical display to demonstrate the data linkage process, including the number of individuals with linked data at each stage.	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable.	8	RECORD 7.1: A complete list of codes and algorithms used to classify exposures, outcomes, confounders, and effect modifiers should be provided. If these cannot be reported, an explanation should be provided.	8
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8-9		

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Bias	9	Describe any efforts to address potential sources of bias	7-9		
Study size	10	Explain how the study size was arrived at	7-8		
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	9-10		
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) *Cohort study* - If applicable, explain how loss to follow-up was addressed *Case-control study* - If applicable, explain how matching of cases and controls was addressed *Cross-sectional study* - If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses	9		
Data access and cleaning methods		..		RECORD 12.1: Authors should describe the extent to which the investigators had access to the database population used to create the study population.	7

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				RECORD 12.2: Authors should provide information on the data cleaning methods used in the study.	
Linkage		..		RECORD 12.3: State whether the study included person-level, institutional-level, or other data linkage across two or more databases. The methods of linkage and methods of linkage quality evaluation should be provided.	7-8
Results					
Participants	13	(a) Report the numbers of individuals at each stage of the study (*e.g.*, numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed) (b) Give reasons for non-participation at each stage. (c) Consider use of a flow diagram	11 + Figure 1	RECORD 13.1: Describe in detail the selection of the persons included in the study (*i.e.,* study population selection) including filtering based on data quality, data availability and linkage. The selection of included persons can be described in the text and/or by means of the study flow diagram.	Figure 1
Descriptive data	14	(a) Give characteristics of study participants (*e.g.*, demographic, clinical, social) and information on exposures and potential confounders (b) Indicate the number of participants with missing data for each variable of interest (c) *Cohort study* - summarise follow-up time (*e.g.*, average and total amount)	11 + Table 1		
Outcome data	15	*Cohort study* - Report numbers of outcome events or summary measures over time *Case-control study* - Report numbers in each exposure	11-12		

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		category, or summary measures of exposure *Cross-sectional study* - Report numbers of outcome events or summary measures			
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	11-12 + figure 2 and table 2		
Other analyses	17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	12		
Discussion					
Key results	18	Summarise key results with reference to study objectives	13		
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	15	RECORD 19.1: Discuss the implications of using data that were not created or collected to answer the specific research question(s). Include discussion of misclassification bias, unmeasured confounding, missing data, and changing eligibility over time, as they pertain to the study being reported.	15-16
Interpretation	20	Give a cautious overall interpretation of results considering objectives,	13-15		

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		limitations, multiplicity of analyses, results from similar studies, and other relevant evidence			
Generalisability	21	Discuss the generalisability (external validity) of the study results	15		
Other Information					
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17		
Accessibility of protocol, raw data, and programming code		..		RECORD 22.1: Authors should provide information on how to access any supplemental information such as the study protocol, raw data, or programming code.	7

*Reference: Benchimol EI, Smeeth L, Guttmann A, Harron K, Moher D, Petersen I, Sørensen HT, von Elm E, Langan SM, the RECORD Working Committee. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) Statement. *PLoS Medicine* 2015; in press.

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