



## Examining quit attempts and successful quitting after recent cigarette tax increases



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### ABSTRACT

As cigarette smoking rates decline, an important policy question is whether increasing cigarette taxes will continue to encourage smoking cessation. We tested this question following recent tobacco tax increases. Data were from the Minnesota Adult Tobacco Survey, a serial cross-sectional telephone survey conducted statewide, and was limited to past-year cigarette smokers in 2010 (n = 1029) and 2014 (n = 1382). Weighted estimates were calculated of the prevalence of past year smokers, smokers who attempted to quit smoking, and those who successfully quit by demographics, tobacco use, use of evidence-based cessation assistance to quit, and smoker perceptions of the tax increases. Among past year smokers, almost 60% reported a quit attempt in both years, 12.8% successfully quit in 2010 and 15.6% in 2014. Although older age, daily smoking, mean cigarettes per day, and more days of e-cigarette use, were associated with quit attempts in unadjusted models, only the perceived tax increase effect (AOR = 8.9; 95% CI 6.3–12.5) and low nicotine dependence (AOR = 1.9, 95% CI 1.3–2.7) were associated with making a quit attempt in adjusted models. Successful 12-month quits were predicted by college education (AOR = 3.2, 95% CI 1.3–7.8), the use of cessation support (AOR = 2.1, 95% CI 1.3–3.6), and reporting the tax increase helped maintain a quit (AOR = 12.3, 95% CI 7.5–20.1). These findings suggest that a large tax increase is effective in promoting quitting even in the presence of strong tobacco control measures such as indoor smoking bans and other smoking restrictions, mass media campaigns, and universal access to cessation support.

### 1. Introduction

Taxes on tobacco products serve dual public policy roles as a source of government revenue and as an effective tobacco control strategy (Chaloupka et al., 2012). When tobacco taxes are large enough and are passed through to the consumer as increased prices, the higher cost of tobacco products encourages some smokers to quit and young people not to start. Higher prices also lead to less smoking and other behavioral responses as smokers seek to reduce their tobacco expenditures (Choi and Boyle, 2017; Xu et al., 2013). The potential utility of increased taxes has been consistently observed across many different countries (Chaloupka et al., 2012), such that increasing taxes is now firmly established as a key strategy of comprehensive tobacco control (Warner, 2014). In 2008, the World Health Organization identified higher taxes as part of the six MPOWER tobacco control measures (<http://www.who.int/tobacco/mpower/en/>), that are designed to

assist countries in implementing the Framework Convention for Tobacco Control (FCTC) (Song et al., 2016), an international treaty developed in response to the global tobacco epidemic. In a recent analysis of the adoption of the MPOWER measures, Levy and colleagues (Levy et al., 2016) estimated that 7 million smoking-attributed deaths had been averted between 2007 and 2014 because countries had increased cigarette taxes.

In the US, cigarette excise taxes are imposed at the national level, across all 50 states, and locally (e.g., Chicago, New York City, Philadelphia). The last national tax increase in 2009 raised the tax on a pack of 20 cigarettes from \$0.39 to \$1.01. Across US states there is a wide variability in the state excise tax rate on a pack of cigarettes, ranging from \$0.17 to \$4.35 (Campaign for Tobacco Free Kids, 2017). Between 2000 and 2009, 46 states increased their cigarette excise taxes, but this policy effort slowed after 2010; since that time, only 14 states had increased excise taxes (Holmes et al., 2016). Through 2016 only 2

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states, New York and Minnesota had imposed a statewide tax increase more than \$1.50 (Holmes et al., 2016).

Minnesota applies an excise tax on cigarettes plus a tax in-lieu of sales tax that is based on the average retail cigarette price. In 2013 when these taxes were increased (+\$1.75), Minnesota more than doubled the total taxes on cigarettes from \$1.59 to \$3.34 (Kleman, 2016), resulting in a 30% increase in the average pack price for cigarettes (Amato et al., 2015). This increase placed Minnesota 7th in a ranking of US state tobacco tax rates (<https://www.tobaccofreekids.org/what-we-do/us/state-tobacco-taxes>).

An important question for public policy research is whether increasing taxes and thus higher prices will continue to be effective at encouraging smokers to quit. This question is particularly relevant in places where the local norms have become strongly anti-smoking and where smoking prevalence rates and sales of cigarettes are declining. As smoking rates are highest among the poor and less-educated, it is particularly important to consider whether tobacco tax increases will have unintended consequences such as increased stigma among smokers or increased tobacco-related health disparities (Hirono and Smith, 2018).

We had an opportunity to consider changes in smoking following 2 recent tax increases. For this analysis we examined typical demographics but in addition we considered smokers' perceptions of the increased tax. The outcomes of interest were quit attempts and quitting after the 2009 federal tax increase and a 2013 Minnesota tobacco tax increase. We considered these tax changes using data from the 2010 and 2014 Minnesota Adult Tobacco Surveys.

## 2. Methods

Data were collected as part of the [Minnesota Adult Tobacco Survey \(MATS\)](#). MATS has been conducted as a series of repeated cross-sectional telephone surveys designed to collect general health and tobacco-related information from a random sample of Minnesota adults aged 18 and older. The last two surveys (2010 and 2014) were included in this analysis. In both years the survey was conducted statewide using a random digit dialing (RDD) sample method for landlines and cellular telephone numbers and the final analytic sample was weighted to represent the entire civilian, non-institutionalized adult population in Minnesota. The RDD response rates, which reflect the net response across both the household screener and the questionnaire, in MATS 2010 were 44.5% for the cell phone sample and 45.0% for the landline sample, and in MATS 2014, 25.2% for the landline sample and 18.8% for the cell phone sample. MATS have been conducted in collaboration with the Minnesota Department of Health (MDH), and the survey instrument and methods were reviewed and approved by the MDH Institutional Review Board (IRB).

Datasets for the current analysis (2010;  $n = 7057$ ) and (2014;  $n = 9304$ ) were limited to past-year smokers in 2010 ( $n = 1029$ ) and 2014 ( $n = 1382$ ) who were current and former smokers (who quit in the past year) at the time of the survey.

### 2.1. Measures

Demographic factors included age, gender, and the highest completed level of education. Current smokers were defined as those who have smoked at least 100 cigarettes in their lifetime and reported smoking every day or some days at the time of interview. Current users of cigars (including cigarillos, little filtered cigars), pipes, and smokeless tobacco (including chewing tobacco, snuff or snus) were defined as those who used these tobacco products at least 20 times in their lifetime and had used the product at least once in the past 30 days. Current users of e-cigarettes and hookah (water pipe) were defined as those who used the product at least once in the past 30 days. Use of e-cigarettes in the past 30 days was further defined as 0, 1–5 and > 5 days based on Amato et al., 2016. For analysis, we designated current use of cigars, pipes, smokeless tobacco, or hookah as 'non-cigarette tobacco use'.

Smoking dependence was measured by the widely accepted item "how soon after you wake up do you smoke your first cigarette?" Response options "within 5 min" and "6–30" minutes were collapsed into "30 min or less" and "31–60" and "after 60 min" were combined to capture "more than 30 min." Past year smokers were asked whether they had intentionally made a quit attempt for a day or longer. Smokers who reported a quit attempt were asked whether they used any cessation aid including nicotine replacement therapy (nicotine gum, patch, lozenge or a nicotine nasal spray or inhaler), prescription medication (Zyban®/bupropion or Chantix®/varenicline), or other behavioral support (telephone helpline, quitting class, on-line help) to quit smoking cigarettes. Any assistance was defined by use of any cessation aid to quit smoking.

In 2010, the cigarette tax increase was described to participants as: "In March of this year, a 61cent cigarette tax increase took effect nationwide." In 2014, the survey said, "Taxes on the purchase of tobacco products have increased in the past 12 months in Minnesota". In both surveys, respondents were asked, 'Did it help you "...think about quitting?', "...cut down on cigarettes?', "...make a quit attempt?', "...maintain a quit?'"

### 2.2. Data analysis

Statistical analyses were conducted using SAS 9.4 (SAS Institute, Cary NC), the *surveyfreqs* and *surveylogistic* procedures. The *surveyfreq* procedure was used to estimate population prevalence rates. The *surveylogistic* procedure was used to conduct weighted bivariate and multivariate logistic regression analyses for the two main dichotomized outcomes (Quit Attempts – yes/no, Successful Quitting among those who attempted to quit during the past 12 months– yes/no). Estimates were weighted to represent the civilian, noninstitutionalized adult population in Minnesota.

Weighted estimates were calculated for MATS 2010 and 2014 for these groups: (1) all past year smokers, (2) past year smokers who attempted to quit smoking, and (3) past year smokers who attempted and successfully quit. These groups were examined by demographics, tobacco use, use of traditional cessation assistance to quit, and smoker perceptions of the tax increases in 2010 and 2014 (Table 1). A bivariate analysis examined associations between all characteristics, and quit attempt and successful quit among those who attempted to quit in the past year in separate models in 2010 and 2014. However, we concluded that providing the data for both years in table form added no new information compared to just reporting 2014. Therefore all reported regression analyses are restricted to 2014 only (Table 2). Independent variables included demographics, e-cigarette use, using other tobacco products, nicotine dependence (time to first cigarette), cessation assistance (i.e., NRT, prescriptions, counseling) among those who successfully quit, and smoker perceptions of the tax increase. Unadjusted odds ratios were calculated in reference to no quit attempt and smokers who did not quit in the past year for each outcome, attempted to quit and successfully quit respectively.

Finally, separate multivariate logistic regression models were fit to predict the two outcomes, quit attempts and 12-month quit among those who attempted to quit (Table 3) in MATS 2014. Daily smoking and mean cigarettes per day, and past 30-day smoking were not included in the models as they were highly correlated with time to first use, a proxy of nicotine dependence. Use of cessation aids was not included in the quit attempt model because the use of cessation aids questions were asked only among those who attempted to quit and inclusion of these variables could inflate the relation between the predictor (use of cessation aids) and outcome (quit attempts). Similarly, perceptions of how the tax increase effected behavior were reflected by one item in each model that was directly associated with the outcome (i.e., help you make a quit attempt, help you maintain a quit). Missing data due to inapplicable questions or other reasons were coded as an independent category (Not Reported) for a few covariates and included in the multivariate models. This analytic strategy retained sample sizes

**Table 1**  
Characteristics of past year smokers, smokers with a quit attempt, and smokers who quit in 2010 and 2014.

Characteristics	Past year smokers <sup>i</sup>		Smokers who attempted to quit in past 12 months <sup>ii</sup>		Smokers who attempted to quit and quit in the past 12 months <sup>iii</sup>	
	MATS 2010 n = 1029	MATS 2014 n = 1382	MATS 2010 n = 619	MATS 2014 n = 830	MATS 2010 n = 117	MATS 2014 n = 205
	Weighted % (95% CI)	Weighted % (95% CI)	Weighted % (95% CI)	Weighted % (95% CI)	Weighted % (95% CI)	Weighted % (95% CI)
Age						
18 to 24	17.9 (14.8–21.0)	12.9 (10.4–15.4)	22.1 (17.8–26.4)	15.9 (12.5–19.3)	17.9 (8.6–27.1)	13.1 (7.1–19.2)
25 to 44	43.7 (39.9–47.5)	45.2 (41.8–48.6)	44.6 (39.7–49.5)	47.1 (42.7–51.5)	46.2 (35.5–56.9)	44.8 (36.4–53.2)
45 to 64	32.9 (29.5–36.2)	35.0 (31.8–38.1)	28.2 (24.2–32.2)	31.6 (27.7–35.5)	27.9 (18.9–36.9)	33.1 (25.3–40.9)
65 or older	5.5 (4.4–6.6)	7.0 (5.6–8.3)	5.1 (3.8–6.4)	5.3 (3.7–6.9)	8.0 (3.6–12.5)	8.9 (4.2–13.8)
Gender						
Male	54.3 (50.5–58.1)	56.9 (53.6–60.3)	53.6 (48.7–58.5)	55.9 (51.5–60.3)	53.0 (42.0–64.0)	60.6 (52.2–69.0)
Female	45.7 (41.9–49.5)	43.1 (39.7–46.4)	46.4 (41.5–51.3)	44.1 (39.6–48.5)	47.0 (36.0–58.0)	39.4 (31.0–47.8)
Education						
Less than high school or GED	14.1 (11.2–17.0)	16.9 (14.2–19.7)	15.2 (11.3–19.2)	14.6 (11.2–18.0)	16.2 (6.3–26.0)	9.9 (4.6–15.3)
High school, some college, or 2-year degree	76.2 (73.0–79.4)	71.0 (67.9–74.1)	74.2 (70.0–78.6)	72.1 (68.2–76.0)	67.7 (57.0–78.4)	71.5 (63.8–79.1)
College graduate or higher	9.8 (8.0–11.6)	12.1 (10.2–14.0)	10.5 (8.1–12.9)	13.3 (10.8–15.8)	16.1 (9.1–23.1)	18.7 (12.5–24.7)
Daily smoker	67.0 (63.4–70.6)	64.1 (60.9–67.4)	55.1 (50.2–60.0)	50.6 (46.1–55.0)	NA	NA
Time to first use						
30 min or less	44.6 (40.5–48.7)	47.7 (44.0–51.4)	39.7 (34.3–45.1)	38.5 (33.6–43.4)	NA	NA
> 30 min	55.4 (51.3–59.5)	52.3 (48.6–56.0)	60.3 (54.9–65.6)	61.5 (56.6–66.4)	NA	NA
Non cigarette tobacco user	16.6 (13.6–19.5)	18.6 (15.7–21.4)	18.1 (14.3–22.0)	18.1 (14.5–21.7)	10.0 (3.8–16.1)	12.0 (6.2–17.7)
Current E-cigarette user	3.2 (1.6–4.7)	27.1 (23.9–30.2)	3.1 (1.2–5.1)	30.6 (26.4–34.8)	0.6 (0.0–1.8)	26.6 (18.7–34.6)
Past 30-day E-cigarette use						
0 day in the past 30 days	61.4 (46.5–76.4)	60.9 (56.7–65.1)	63.5 (45.2–81.8)	58.7 (53.4–63.9)	87.3 (81.9–92.6)	59.7 (48.8–70.1)
1–5 days in the past 30 days	30.6 (16.1–45.0)	21.7 (18.1–25.2)	18.7 (4.4–33.0)	20.9 (16.5–25.3)	12.7 (7.4–18.1)	14.6 (6.2–22.9)
6+ days in the past 30 days	8.0 (0.1–15.9)	17.4 (14.1–20.8)	17.8 (2.8–32.9)	20.4 (16.1–24.7)	0	25.7 (15.8–35.7)
<sup>a</sup> Perceived effects of tax increase on smoking						
Help you think about quitting?	51.0 (47.2–54.9)	60.8 (57.5–64.2)	62.4 (57.7–67.1)	72.0 (68.0–76.0)	52.5 (41.5–63.4)	71.0 (63.2–78.8)
Help you to cut down on cigarettes?	41.4 (37.6–45.2)	48.1 (44.7–51.6)	50.0 (45.1–54.9)	56.6 (52.1–61.0)	30.1 (20.1–40.2)	47.2 (38.6–55.8)
Help you make a quit attempt?	38.4 (34.6–42.2)	44.2 (40.7–47.6)	55.3 (50.4–60.1)	62.9 (58.6–67.2)	43.1 (31.9–54.3)	64.2 (55.8–72.6)
Help you maintain a quit?	14.8 (12.0–17.6)	18.8 (16.2–21.5)	21.6 (17.6–25.6)	27.9 (24.0–31.9)	41.9 (31.3–52.8)	63.8 (55.4–72.3)
<sup>b</sup> Used any assistance	NA	NA	49.0 (44.1–53.9)	33.2 (29.1–37.3)	51.1 (41.0–61.2)	43.9 (35.3–52.4)
<sup>b</sup> Used any NRT	NA	NA	31.1 (26.4–35.7)	23.7 (20.0–27.3)	26.5 (17.0–36.0)	30.1 (22.2–38.1)
<sup>b</sup> Used prescription medications	NA	NA	46.1 (41.2–51.0)	31.0 (27.0–35.0)	48.2 (38.0–58.3)	41.0 (32.2–49.2)
<sup>b</sup> Used behavioral counseling	NA	NA	18.6 (14.7–22.6)	9.0 (6.4–11.6)	13.7 (7.0–20.4)	9.3 (4.2–14.4)

MATS: Minnesota Adult Tobacco Survey.

Shown are column percents.

Current users of non-cigarette tobacco product were defined as current use of cigars, pipes, smokeless tobacco, and hookah.

Current users of e-cigarettes were defined as those who used the product at least once in the past 30 days. Use of e-cigarettes was further defined as 1–5 or 6 or more days in the past 30 days.

Confidence interval (CI) calculated using Wald method.

NA: Not applicable.

<sup>i</sup> Includes past-year smokers who were current and former smokers (last smoked regularly any time in the past 12 months) at the time of the survey at both waves (MATS 2010 (n = 1029) and 2014 (n = 1382)).

<sup>ii</sup> Includes past year smokers who attempted to quit for one day or longer in the 12 months because they were trying to quit (MATS 2010 (n = 619) and 2014 (n = 830)).

<sup>iii</sup> Includes past year smokers who attempted to quit and successfully quit in the past 12 months (MATS 2010 (n = 117) and 2014 (n = 205)).

<sup>a</sup> Questions asked in 2010 and 2014 are not comparable. In 2010, the question was worded as “In March of 2009, a 61 cent cigarette tax increase took effect nation-wide. What effects if any, did this price increase have on your smoking?” “Did it help you “...think about quitting?”, “...cut down on cigarettes?”, “...make a quit attempt?”, “...maintain a quit?”” In 2014, the question on tax was based on the statewide tax increase in Minnesota: “Taxes on the purchase of tobacco products have increased in the past 12 months in Minnesota. What effects if any, did this price increase have on your smoking?” “Did it help you “...think about quitting?”, “...cut down on cigarettes?”, “...make a quit attempt?”, “...maintain a quit?””

<sup>b</sup> Questions on smoking cessation aids were asked of past year smokers who attempted to quit in past 12 months.

in the full models for the two outcomes.

### 3. Results

The prevalence of current cigarette smoking fell from 16.1% in 2010 to 14.4% in 2014 and current e-cigarette use increased (0.7% in 2010; 5.9% in 2014). These comparisons have been described previously (Minnesota Adult Tobacco Survey; Boyle et al., 2015). Considering both smokers and recent quitters, past year cigarette smoking was consistent across both surveys 18.7% in 2010 and 17.3% in 2014. Among these

past year smokers, almost 60% reported a quit attempt in both time points and 15.6% successfully quit in 2014 and 12.8% in 2010. Compared to 2010, significantly more smokers who attempted to quit reported e-cigarette use (30.6% in 2014 versus 3.1% in 2010) and thought about quitting because of the tax increase (72% in 2014 versus 62.4% in 2010) and fewer reported use of any cessation aids in 2014 (49% in 2010 and 33.2% in 2014). Only 9% of those who attempted to quit in 2014 reported use of behavioral support (class, helpline, on-line help) which was almost half compared to 2010. Past 12-month quitters in 2014 were more likely than those in 2010 to report taxes helped

**Table 2**  
Bivariate associations of past 12-month quit attempts and successful 12-month quits in MATS 2014.

Characteristics	Attempted to quit in past 12 months OR (95%CI)	Quit in the past 12 months OR (95%CI)
<b>Age</b>		
18 to 24	Ref	Ref
25 to 44	0.9 (0.6–1.5)	1.0 (0.5–1.7)
45 to 64	0.7 (0.4–1.1)	1.2 (0.6–2.3)
65 or older	0.4 (0.2–0.7)	2.3 (0.9–5.7)
<b>Gender</b>		
Male	Ref	Ref
Female	1.0 (0.8–1.4)	0.8 (0.5–1.2)
<b>Education</b>		
Less than high school or GED	Ref	Ref
High school, some college, or 2-year degree	1.3 (0.9–2.0)	1.6 (0.8–3.1)
4 year college or higher	1.2 (0.8–1.9)	2.6 (1.2–5.7)
Daily smoker	0.5 (0.4–0.7)	NA
Mean cigarettes per day	0.9 (0.9–1.0)	NA
Past 30-day smoker	0.7 (0.5–1.0)	NA
<b>Time to first use</b>		
30 min or less	Ref	NA
More than 30 min	1.9 (1.4–2.5)	NA
Non cigarette tobacco user	0.9 (0.6–1.2)	0.6 (0.3–1.0)
<b>Past 30-day E-cigarette user</b>		
0 day in the past 30 days	Ref	Ref
1–5 days in the past 30 days	0.9 (0.6–1.4)	0.6 (0.3–1.4)
6+ days in the past 30 days	2.0 (1.2–3.3)	1.3 (0.7–2.4)
<b>Effects of tax increase on smoking</b>		
Help you think about quitting?	4.1 (3.1–5.5)	0.9 (0.6–1.4)
Help you to cut down on cigarettes?	2.7 (2.1–3.6)	0.6 (0.4–0.9)
Help you make a quit attempt?	8.8 (6.3–12.4)	1.1 (0.7–1.7)
Help you maintain a quit?	NA	9.6 (6.0–15.4)
Used any cessation assistance	NA	1.8 (1.2–2.8)
Used any nicotine replacement therapy	NA	1.6 (1.0–2.4)
Used prescription medications	NA	1.7 (1.2–2.7)
Used behavioral counseling	NA	1.0 (0.5–2.1)

Analysis and results for 2010 were similar and are not reported here.

them think about quitting (71.0% in 2014 and 52.5% in 2010), cut down (47.2% in 2014 and 30.1% in 2010), make a quit attempt (64.2% in 2014 and 43.1% in 2010), and maintain a quit (63.8% in 2014 and 43.1% in 2010).

Table 2 reports unadjusted bivariate predictors of past 12-month quit attempts and successful 12-month quits in 2014 (the results for 2010 were similar and are not reported). Smokers 65 or older and daily smokers were less likely to make an attempt to quit cigarettes. While those who smoke > 30 min after waking, those who reported the tax effected their smoking, those who used e-cigarettes on 6 or more days compared to non-past 30-day users, and those who used cessation aides were more likely to make a quit attempt. Successful 12-month quits were predicted by higher education (OR = 2.6, 95% CI 1.2–5.7), reporting the tax increase helped maintain a quit (OR = 9.6, 95% CI 6.0–15.4), and the use of cessation assistance.

Table 3 presents adjusted odds ratios from the multivariate models predicting both outcomes of interest in 2014: quit attempts and 12-month quits among past year cigarette smokers (the results for 2010 were similar and are not reported). For quit attempts, the strongest effect was found for perception of the tax increase helping smokers to make a quit attempt (AOR = 8.9, 95% CI 6.3–12.5) after factoring in age group, gender, education, time to first use, non-cigarette tobacco use, and current e-cigarette use status. In addition, the odds of attempting to quit were higher among those who were less dependent on nicotine (time to first use > 30 min) compared to those who smoked cigarette within 30 min of waking up.

From the multivariate model predicting successful quitting in the

**Table 3**  
Adjusted odds ratios for past year cigarette smokers who attempted to quit smoking and who successfully quit in MATS 2014.

Characteristics	Attempted to quit in past 12 months OR (95%CI)	Quit in the past 12 months OR (95%CI)
<b>Age</b>		
18 to 24	Ref	Ref
25 to 44	1.1 (0.6–1.8)	1.1 (0.4–2.6)
45 to 64	1.2 (0.7–2.1)	1.1 (0.5–2.7)
65 or older	0.6 (0.3–1.2)	2.8 (0.7–10.1)
<b>Gender</b>		
Male	Ref	Ref
Female	0.9 (0.7–1.3)	0.7 (0.4–1.1)
<b>Education</b>		
Less than high school or GED	Ref	Ref
High school, some college, or 2-year degree	1.3 (0.8–2.2)	1.3 (0.6–2.8)
4 year college or higher	1.4 (0.8–2.4)	3.2 (1.3–7.8)
<b>Time to first use</b>		
30 min or less	Ref	NA
More than 30 min	1.9 (1.3–2.7)	NA
<sup>a</sup> Not reported	2.9 (1.8–4.7)	NA
<b>Non cigarette tobacco user</b>		
No	Ref	Ref
Yes	0.8 (0.5–1.2)	0.5 (0.2–1.1)
<sup>a</sup> Not reported	1.1 (0.2–5.0)	1.4 (0.3–6.0)
<b>Past 30-day E-cigarette user</b>		
0 day in the past 30 days	Ref	Ref
1–5 days in the past 30 days	0.8 (0.5–1.3)	0.5 (0.2–1.2)
6+ days in the past 30 days	1.6 (0.9–2.9)	0.8 (0.4–1.7)
<sup>a</sup> Not reported	0.5 (0.3–0.7)	1.1 (0.6–2.1)
<b>Effects of tax increase on smoking</b>		
Help you make a quit attempt?	8.9 (6.3–12.5)	NA
Help you maintain a quit?	NA	12.3 (7.5–20.1)
Used any cessation assistance	NA	2.1 (1.3–3.6)

Analysis and results for 2010 were similar and are not reported here.

<sup>a</sup> Indicates missing data due to inapplicable questions or other reasons were included as an independent category.

past 12 months among those who attempted to quit, positive perception that the tax increase helped maintain a quit was also the strongest predictor of past year quitting (AOR = 12.3, 95% CI 7.5–20.1) after adjusting for age group, gender, education, non-cigarette tobacco use, current e-cigarette use status, and use of any assistance to quit. The odds of a successful quit were higher for smokers with college degree or higher (AOR = 3.2, 95% CI 1.3–7.8) compared to those with less than high school degree or GED. Successful quit was also predicted by the use of cessation aides (AOR = 2.1, 95% CI 1.3–3.6).

#### 4. Discussion

This study has contributed to our increased understanding of tobacco taxes by examining smoker perceptions following both the 2009 federal tax increase and a 2013 state tax increase. After both tax increases we estimated > 10% of Minnesota smokers quit smoking. These are robust effects in a state with a mature tobacco control program. In particular, Minnesota has benefited from sustained tobacco control funding that resulted from a separate tobacco industry lawsuit settlement. This has included mass media campaigns to support statewide cessation services ([www.quitplan.com](http://www.quitplan.com)) and promote tobacco control public policy (Centers for Disease Control and Prevention (CDC), 2011a). In addition these results support the role of taxation even as prevalence rates are falling. Both quit estimates are larger than other US population-based estimates of annual quit rates. Examining national data from the US Health Interview Survey (NHIS), Malarcher and colleagues (Centers for Disease Control and Prevention (CDC), 2011b) estimated 6.2% of US adults quit in 2010. More recently, Babb and

colleagues (Babb et al., 2017) reported 7.4% of past year smokers had quit in 2015. Zhu and colleagues analyzed the Current Population Survey and found the population cessation rate increased in 2014–15 (5.6%) compared to 2010–11 (4.5%) (Zhu et al., 2017).

A number of previous studies have measured changes in prevalence, quits, initiation, and sales following tobacco tax increases. For example, smoking prevalence in New York City was estimated to have fallen 11% following a series of tobacco control efforts including a city excise tax increase in 2002 (Frieden et al., 2005). Reed and colleagues (Reed et al., 2008) were able to add questions to the California Tobacco Survey following a 1998 tax increase and found significantly increased quit attempts and successful quits. Van Hasselt and colleagues (van Hasselt et al., 2015) found reductions in smoking among youth and young adults following the 2009 Federal tax increase. Outside the US, several recent papers have reported the impact of cigarette tax increases on recent quits. Dunlop and colleagues (Dunlop et al., 2011) used an on-going weekly tracking survey to assess the impact of a 25% increase in 2010 on cigarette taxes in Australia. They reported 22% of smokers had quit or tried to quit in the month after the tax compared to 12% in the same month the year earlier. Germany increased the cigarette tax by about 1 Euro or 33% across 5 annual increases (2001–2006), and based on population-based surveys across the time period, 4% to 7.9% of smokers reported quitting (Hanewinkel and Isensee, 2007). New Zealand has also adopted annual increases (10%) in their tobacco tax between 2010 and 2016 (Li et al., 2015). Using cross-sectional and panel surveys, researchers found small effects (< 3%) based on quitting in the prior 2 weeks, but larger effects when considering quit attempts and other changes in smoking behaviors (Li et al., 2017; Walton et al., 2013). In a population-based longitudinal survey of Mexican adult smokers, 13% reported a recent quit following a 2007 tax that increased the price about 14% (Saenz-de-Miera et al., 2010).

In this study, among Minnesota adult smokers who reported making a quit attempt, over half stated the tax helped them think about quitting, cut down on cigarettes, and make a quit attempt in both 2010 and 2014. The higher state-tax increase in 2013 yielded greater positive perception that the tax helped smokers make a quit attempt in 2014 compared to 2010: 64.2% (55.8–72.6) vs 43.1% (31.9–54.3). Among those who successfully quit cigarettes in 2014, almost 2/3rds of quitters reported the tax helped them to maintain the quit. This effect was retained in multivariable regression models indicating that beyond demographic predictors and use of other products or cessation aides, the perception that the cigarette tax helped maintain abstinence was highly related to successful quitting.

Although the overall impact of the perceived effect of the state tax increase on quitting behavior was robust, it is noteworthy that completing more years of education predicted quitting in the adjusted model. In a previous analysis of smoking prevalence trends in Minnesota, we observed a widening gap in smoking by education level (Boyle et al., 2017). However, others have found cigarette tax increases associated with neutral (Zhu et al., 2010) or lower smoking-related disparities (Brown et al., 2014; Siahpush et al., 2009). A previous paper, using the same MATS 2014 sample, found a majority of smokers, particularly low socioeconomic (SES) smokers, had taken behavioral steps toward quitting in response to the 2013 tax (Parks et al., 2017). Ideal cigarette tax policy would result in reduced smoking among low SES smokers thus reducing tobacco-related disparities and advancing health equity. However, simply increasing taxes without cessation support may increase inequality and other unintended consequences including illicit tobacco markets (Hirono and Smith, 2018). Perhaps the best course forward is the dedication of tax funds toward comprehensive cessation assistance for those who smoke at disproportionate rates through an enhanced tobacco education campaign (Hirono and Smith, 2018; Garrett et al., 2015; Institute of Medicine, 2007).

In 2013, the median past year quit attempt rate across all US states was 65.9% (Lavinghouze et al., 2015). We estimated 60% of past year smokers in Minnesota made a quit attempt in 2014 which remains

lower than the healthy people 2020 goal of 80% (Healthy People 2020). However, in addition to quit attempts we have observed other public health benefits from the tax increase. For example, there was a large reduction in the sales of cigarettes at convenience stores in the 6 months following the tax increase; (Amato et al., 2015) a large increase in enrollments for smoking cessation services; (Keller et al., 2015) and changes in cigarette expenditure minimizing strategies, especially among smokers with less completed education (Choi and Boyle, 2017).

As we had expected, the use of e-cigarettes among smokers who attempted to quit was much higher in 2014 (30.6%) compared to 2010 (3.1%). In 2014, the use of e-cigarettes on 6+ days in the past 30 days was associated with a greater likelihood of making a quit attempt in an unadjusted model. In the multivariable model, e-cigarette use was not found to significantly predict quit attempts. Use of e-cigarettes among successful quitters in this sample was low (unweighted sample size of 6+ days = 30 and 1–6 days = 13). We applied an appropriate measure of e-cigarette use (Amato et al., 2016), and the overall analysis sample was considered adequate for each of the two outcomes of interest, given the number of predictors. However, the question of the role of e-cigarette use in smoker quit attempts will require a larger longitudinal study to better explore e-cigarette use and cigarette cessation. For example, a recent study from England used time series analysis with a population-based aggregated sample of 1200 smokers and found a significant positive association between e-cigarette use and successful quit attempts (Beard et al., 2016). Similarly, an analysis (n = 5124) of waves 1 and 2 of the Population Assessment of Tobacco and Health Study, found smokers who started using e-cigarettes daily were more likely to quit smoking compared to e-cigarette nonusers (Berry et al., 2018).

Although e-cigarette use increased from 2010 to 2014, there were decreases in the use of evidence-based cessation aides over the same time period. Despite these declines, any use of cessation aides (i.e., NRT, behavioral counseling, or prescription medications) was associated with successful quitting.

Some important limitations should be considered when interpreting the results of this study. First, the data rely on self-reported behavior that was collected in a cross-sectional survey at least 6 months after the tax increase and for which we have no control period. We are relying on serial cross-sectional surveys that used the same survey vendor, set of questions, and survey methods but in 2 different time periods. Although this statewide survey has benefitted from consistent methods, the RDD response was lower in 2014 which is consistent with trends in other general population surveys. Second, the racial/ethnic composition of Minnesota's population was too homogenous to explore racial/ethnic differences in the tobacco outcomes. Third, while the analytic approach extends previous work in this area by modeling self-reported perceptions of the effect of the 2013 tax increase on 2014 behavior, there may be other explanatory variables that were not measured in this survey. Fourth, our results may have been limited by low sample size of successful quitters in some groups, such as those who use e-cigarettes regularly.

Prior to the 2013 tax increase in Minnesota, the statewide smoking prevalence was about 16%, so an important finding from this paper is that a large tax increase remains effective even in the presence of strong tobacco control measures (Centers for Disease Control and Prevention (CDC), 2011a) (indoor smoking ban and other smoking restrictions, mass media campaigns, universal access to cessation support). The results of this study suggest increasing cigarette taxes and providing access to evidenced-based cessation assistance remain essential components of comprehensive tobacco control policies that need to be maintained and targeted to subgroups most at risk for tobacco use and its deadly health consequences.

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## Conflicts of interest

The authors report no conflicts of interest.

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