Decreased Cigarette Smoking but No Change in Use of Electronic Cigarettes Following a University-Wide Smoking Ban

Substance Abuse: Research and Treatment
Volume 13: 1–5

DOI: 10.1177/1178221819874351

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ABSTRACT: The prevalence of electronic cigarette use is increasing, particularly among youth. This recent trend is troubling given that electronic cigarette use is associated with future cigarette smoking. Here, we assessed the prevalence of cigarette smoking and use of electronic cigarettes among college students before and after implementation of a university-wide smoking ban on campus. We found that after the smoking ban was implemented, the prevalence of self-reported combustible cigarette smoking decreased (12% versus 7%; unadjusted: OR = 0.55, 95% CI = 0.34, 0.89, $p = 0.015$), but we did not observe a difference in the prevalence of electronic cigarette use (26.3% versus 27.5%; unadjusted: OR = 1.06, 95% CI = 0.78, 1.43, $p = 0.699$). Future studies should identify factors that increase the impact of university smoking policies on electronic cigarette use.

KEYWORDS: electronic cigarettes, tobacco cigarettes, smoking

RECEIVED: August 5, 2019. **ACCEPTED:** August 11, 2019.

TYPE: Original Research

FUNDING: The author(s) received no financial support for the research, authorship, and/or publication of this article.

DECLARATION OF CONFLICTING INTEREST: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Cigarette smoking causes disease and death. In the United States, 480 000 deaths each year are attributable to combustible cigarette smoking, with >41 000 of these deaths due to secondhand smoke exposure.[1] As the negative health consequences of combustible cigarette smoking are widely known, there is an increasing trend in the United States for people who have never smoked cigarettes to use electronic cigarettes (e-cigs).[2] One of the most alarming patterns of recent findings is the increasing prevalence of e-cigs use among youth. A recent study showed that from 2017 to 2018, the proportion of high school students who used e-cigs in the past 30 days increased from 11.7% to 20.8%.[3] A study of young adults (18-24) showed that among those who used some tobacco product in the past 30 days, the proportion of those who used e-cigs increased from 5.2% in 2011 to 21.8% in 2015.[4] This recent trend is particularly troubling given mounting evidence showing use of e-cigs predicts future combustible cigarette smoking.[5-8]

Based on reports of the harmful effects of combustible cigarette smoking and use of e-cigs,[9-12] many government institutions, private companies, and public universities now have policies in place that in some way restrict or completely ban the use of e-cigs and/or combustible cigarette smoking. A review of 20 studies of smoking bans in public places showed evidence of decreased smoking prevalence that ranged from −7.4% to −31.9%.[13]

A review of 26 studies on the effects of smoking bans in workplaces showed a −3.8% average reduction in smoking prevalence.[14] A study of college students showed that from 2007 to 2009, smoking prevalence decreased at one university following implementation of a smoking ban from 16.5% to 12.8%, whereas cigarette smoking remained relatively unchanged at a control university that did not implement a smoking ban (9.5-10.1%).[15] While these studies suggest smoking bans in a variety of contexts have the potential to decrease smoking prevalence, none of these studies determined the impact of smoking bans on e-cig use.

The effect of smoking bans on e-cig use is of particular interest because of the recent trend of increasing e-cig use among youth.[2-4] A report from a large university in the southwestern United States showed that implementation of a cigarette smoking ban on campus was associated with a small decrease in self-reported combustible cigarette smoking (14.7% pre-ban, 13.3% post-ban), and an increase in use of e-cigs (4.6% pre-ban, 8.3% post-ban).[16] While the potential effect of campus smoking policies on combustible cigarette smoking is promising, an increase in use of e-cigs may be an unintended consequence. Conversely, the addition of an e-cig ban to an existing combustible cigarette smoking ban was associated with no change in current e-cig use three years later (6.7% pre-ban, 6.7% three-years after ban).[17] The impact of smoking bans on college campuses is particularly important because many adolescents do not become regular/heavy users until young adulthood (18-24 years old).[18] Moreover, the negative health effects of smoking are greatly attenuated in individuals who quit smoking prior to the age of 30 compared to those who continue to smoke past the age of 30.[19] However, more studies are needed to assess the impact of campus-wide smoking bans on the prevalence of both combustible cigarette smoking and use of e-cigs.

Thus, the aim of this paper was to assess the prevalence of combustible cigarette smoking and use of e-cigs among college students before and after a university-wide smoking ban. The semester before and semester after a campus smoking ban was implemented, we asked independent groups of undergraduates

whether they had smoked cigarettes or used an electronic cigarette in the past 30 days. We specifically examined use in the past 30 days to assess the potential for immediate changes in prevalence of smoking that could be temporally related to the change in institutional smoking policy.

Method

Study design and participants

To investigate the potential effects of a university-wide smoking ban, we administered a survey the semester before and immediately after the smoking ban to independent groups of undergraduate students. As part of a larger survey to screen individuals for participation in research, two questions were included about frequency of cigarette smoking and electronic cigarettes in the past 30 days: 'What is your best estimate of the number of days you smoked part or all of a cigarette in the past 30 days?' and 'What is your best estimate of the number of days you smoked part or all of an electronic cigarette or vaping device during the past 30 days?' Responses to these questions were binarized into 'yes' or 'no' responses to quantify prevalence of recent cigarette smoking and recent use of electronic cigarettes. A total of 1636 individuals completed the survey as a requirement for participation in studies conducted by researchers in the Psychology Department. Participants with missing data on any of our variables of interest were eliminated (n = 166, 10.1%), resulting in a total sample of 1470 individuals.

The university-wide smoking policy that was implemented in our study defined smoking as inhaling, exhaling, burning, or carrying any lighted cigar, cigarette (including an electronic cigarette or similar device), pipe, or other lighted tobacco product, in any manner or in any form. This policy banned smoking at all campuses, centers, units and institutes which included all land, grounds, buildings, structures, and any other physical property owned or operated by the university; and all motor vehicles owned, leased, or operated by the university. The policy also included the prohibition of smoking in private vehicles when parked or operated on university property. The policy applied to all university students, employees, contractors, and visitors. Compliance and enforcement of the policy was centered around university employees and students submitting reports of violations to the university, which may result in disciplinary action. The full policy can be found online.[20]

Statistical analysis

All analyses were conducted using two-tailed tests in SPSS 25. Bootstrapping was performed (10 000 samples) to calculate 95% confidence intervals (CI) for the overall prevalence statistics. Propensity score matching was conducted using a SPSS implementation of several R packages (version 3.0.4) to create two subsamples of participants (before versus after smoking ban implementation) that were matched on demographic variables.[21-28] Specifically, the propensity that each participant completed our survey before the smoking ban implementation was calculated using a logistic regression model with age, sex, race, and year in college (freshman, sophomore, junior, senior) as covariates. Participants who completed the survey before the smoking ban implementation were matched with their nearest neighbor who completed the survey after the smoking ban implementation based on the propensity scores. A 1:1 matching ratio was used without replacement to create subsamples of equal size. The result was two subsamples that were essentially identical with respect to our demographic covariates.

Participants who were not matched were excluded from analyses. The propensity score matched sample was modeled using logistic regression to calculate an odds ratio to estimate the relationship between implementation of the smoking ban and the likelihood of recent cigarette smoking/e-cig use. The crude logistic regression models included recent cigarette smoking or recent use of e-cigs (yes versus no) as the dependent variable with semester as the predictor (before versus after smoking ban). The adjusted models included age, sex, race, and year in college as covariates. Figures were created using the ggplot2 package in R.[29]

Results

Sample demographics

A total of 1470 individuals (572 before smoking ban; 898 after smoking ban) with complete information about their recent use and covariates were included in our study prior to propensity score matching. A total of 852 individuals (426 before smoking ban; 426 after smoking ban) were included after propensity score matching. Demographic characteristics of the samples before and after propensity score matching are shown in Table 1.

Combustible cigarette smoking before and after smoking ban

The prevalence of recent combustible cigarette smoking was 12.0% (95% CI = 9.0, 15.1) before the smoking ban and 7.0% (95% CI = 4.7, 9.6) after the smoking ban (see Figure 1). Logistic regression analyses showed that the participants were less likely to report recent cigarette smoking in the semester following the smoking ban (unadjusted: OR = 0.55, 95% CI = 0.34, 0.89, $p = 0.015$; adjusted for age, sex, race, and year in college: OR = 0.55, 95% CI = 0.34, 0.90, $p = 0.017$).

Prevalence of electronic cigarette use before and after smoking ban

The prevalence of recent electronic cigarette use was 26.3% (95% CI = 22.2, 30.5) before the smoking ban and 27.5% (95% CI = 23.3, 31.8) after the smoking ban. Logistic regression analyses showed no reliable difference in recent e-cig use in the semester following the smoking ban (unadjusted: OR = 1.06,

Table 1. Demographic characteristics of the study sample.

TOTAL SAMPLE, *N* = 1 470		BEFORE PROPENSITY SCORE MATCHING		AFTER PROPENSITY SCORE MATCHING	
		BEFORE SMOKING BAN (N = 572)	AFTER SMOKING BAN (N = 898)	BEFORE SMOKING BAN (N = 426)	AFTER SMOKING BAN (N = 426)
Age*	18 (18-26)	19 (18-26)	18 (18-26)	19 (18-26)	19 (18-26)
Race/ethnicity					
Non-Hispanic European American/White	1 157 (78.7%)	453 (79.2%)	704 (78.4%)	313 (73.5%)	326 (76.5%)
African-American/Black	118 (8%)	51 (8.9%)	67 (7.5%)	50 (11.7%)	39 (9.2%)
Asian/Asian American/Pacific Islander	90 (6.1%)	32 (5.6%)	58 (6.5%)	28 (6.6%)	28 (6.6%)
Bi- or multiracial	57 (3.9%)	23 (4%)	34 (3.8%)	23 (5.4%)	20 (4.7%)
Hispanic/Latino(a)	44 (3%)	11 (1.9%)	33 (3.7%)	10 (2.3%)	11 (2.6%)
Native American/American Indian	4 (0.3%)	2 (0.3%)	2 (0.2%)	2 (0.5%)	2 (0.5%)
Sex					
Male	523 (35.6%)	331 (57.9%)	616 (68.6%)	242 (56.8%)	255 (59.9%)
Female	947 (64.4%)	241 (42.1%)	282 (31.4%)	184 (43.2%)	171 (40.1%)
College year					
Freshman	991 (67.4%)	323 (56.5%)	668 (74.4%)	226 (53.1%)	235 (55.2%)
Sophomore	313 (21.3%)	169 (29.5%)	144 (16%)	131 (30.8%)	129 (30.3%)
Junior	122 (8.3%)	60 (10.5%)	62 (6.9%)	49 (11.5%)	46 (10.8%)
Senior	44 (3%)	20 (3.5%)	24 (2.7%)	20 (4.7%)	16 (3.8%)

*The median age is reported, along with the minimum and maximum in parentheses. Raw counts and percentages are reported for all other variables.

95% CI = 0.78, 1.43, $p = 0.699$; adjusted for age, sex, race, and year in college: OR = 1.04, 95% CI = 0.76, 1.42, $p = 0.780$).

Discussion

We assessed changes in combustible cigarette smoking and use of e-cigs before and after the implementation of a university-wide smoking ban. Using a self-report measure of use in the past 30 days, our data suggest that a university smoking ban may be associated with a small decrease in combustible cigarette smoking but not use of e-cigs, despite the fact that the smoking ban applied to both types of cigarettes. This distinction is important because our data show that e-cigs were roughly three times more prevalent than combustible cigarette smoking in our college aged sample.

While previous studies of smoking bans have shown evidence of decreased combustible smoking prevalence,[13-15] studies on the effects of smoking bans on e-cigs are lacking. One recent study of changes following a university smoking ban reported a small reduction (14.7% pre-ban, 13.3% post-ban) in self-reported combustible cigarette smoking in the year following a smoking ban,[16] whereas we observed a somewhat larger reduction (13.2% pre-ban, 7.7% post-ban) in self-reported combustible cigarette smoking in the semester following the ban. In the Figueroa et al study, recent use of e-cigs actually increased (4.6% pre-ban, 8.3% post-ban) following the ban, whereas our data showed no reliable difference in recent e-cig use in the semester following the smoking ban. One notable difference between the study sites is that the policy implemented at the university in the Figueroa et al study only included a ban of combustible cigarette smoking on campus and not use of e-cigs, whereas the policy implemented at our institution included a ban of both. This may account for the null findings with e-cig use in our study. Another notable difference is that the prevalence of e-cig use in Figueroa et al was relatively low compared to our sample. It may be that the increase in e-cig use following the smoking ban was blunted because of a ceiling effect resulting from the high prevalence of e-cig use in our sample.

More specifically related to the ban of e-cigs on college campuses, a recent multiyear study reported prevalence of current e-cig use (6.7% pre-ban, 7.4% one-year after ban, 11.1% two-years after ban, 6.7% three-years after ban) following modification of a campus-wide smoking ban to include e-cigs.[17] An important point from this study is that the year-to-year variability in current e-cig use following the ban highlights the difficulty for observational studies like ours to estimate the true

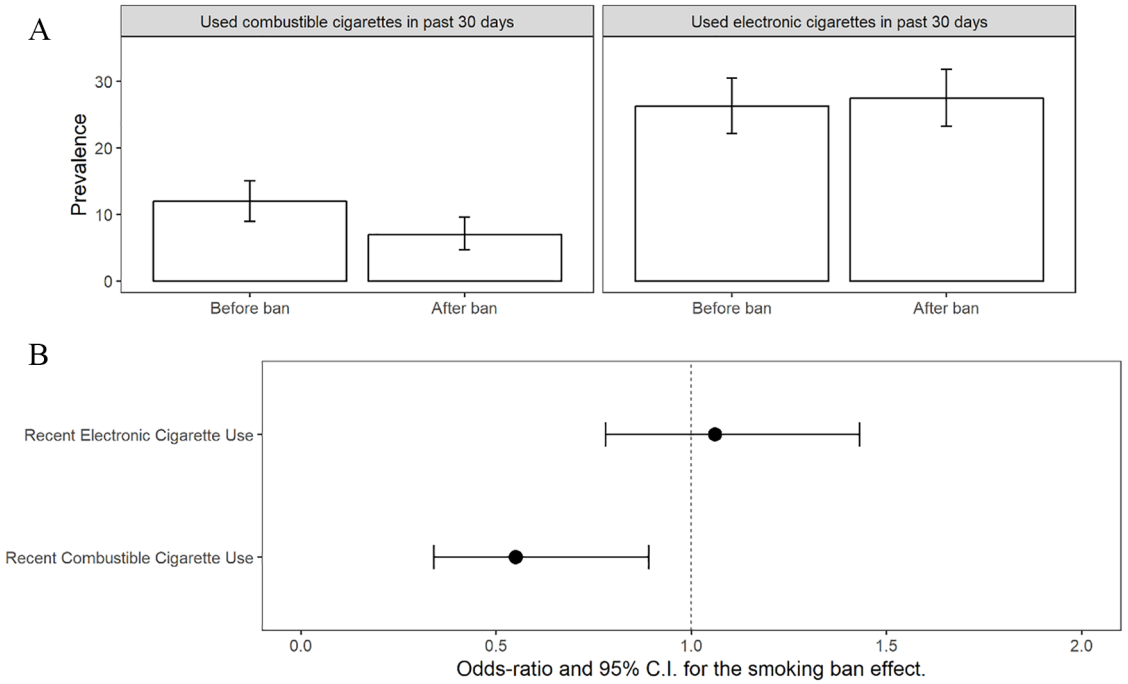

Figure 1. (A) Prevalence of combustible and electronic cigarette use before and after smoking ban surrounded by bootstrapped 95% confidence intervals (CI). (B) Odds ratio and 95% CI for the effect of the smoking ban on the odds of recent use of combustible and electronic cigarettes.

effect of a campus-wide ban on current use when the same cohort is not followed up. Nonetheless, our findings are consistent with this study in that both show relatively little acute change in current e-cig use following a campus-wide e-cig ban, similar to previous cross-sectional and longitudinal studies of cigarette smoking bans on college campuses.[15,30]

One extremely important limitation in our study was the examination of separate groups of college students before and after implementation of the smoking ban. It would have been preferable to examine the effect of a university smoking ban by following the same students over time and comparing rates of each type of smoking before and after the smoking ban. Assessment of attempts to quit either type of smoking would also provide valuable information. Thus, in the present study, we cannot rule out the possibility that the differences in prevalence rates we observed may have been caused by other factors unrelated to the institutional change in smoking policy. The lack of experimental control inherent in our observational design requires caution regarding the conclusions that can be drawn from the study. Nonetheless, our observed change in prevalence of combustible cigarette smoking was similar in magnitude to others studies of campus-wide smoking bans, and the sample size was likely large enough to detect a potential change in recent use of e-cigs if a change had indeed occurred. Future studies should identify factors that make university smoking policies have an impact on e-cig use in youth.

Author Contribution

BA wrote the first draft and conducted all analyses. GLS contributed to the data analytic plan, draft revision, and expert opinion.

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