Original investigation

Evaluating State-Level Differences in E-cigarette and Cigarette Use Among Adults in the United States Between 2012 and 2014: Findings From the National Adult Tobacco Survey

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Abstract

Objective: To examine the association between state-level tobacco control measures and current use estimates of both e-cigarettes and cigarettes, while accounting for socio-demographic correlates.

Methods: Using the 2012–2013 and 2013–2014 National Adult Tobacco Survey (NATS), we assessed prevalence estimates of US adults' e-cigarette and cigarette current use. Four state groups were created based on the combined state-specific prevalence of both products: low cigarette/e-cigarette ($n = 15$), high cigarette/e-cigarette ($n = 16$), high cigarette/low e-cigarette ($n = 11$), and low cigarette/high e-cigarette ($n = 9$). To evaluate the implementation of state-level tobacco control measures, Tobacco Control Index (TCI) was calculated using the State of Tobacco Control annual reports for 2012 and 2013. Multinomial logistic regression models were used to examine differences among the four groups on socio-demographic factors and TCI. Low cigarette/e-cigarette group was used as the referent group.

Results: Current use estimates of each product varied substantially by state; current e-cigarette use was highest in Oklahoma (10.3%) and lowest in Delaware (2.7%), and current cigarette use was highest in West Virginia (26.1%), and lowest in Vermont (12.6%). Compared to low cigarette/e-cigarette, all other US-state categories had significantly lower TCI scores (high cigarette/e-cigarette: adjusted Relative Risk Ratio [aRRR] = 0.61; 95% confidence interval [CI]: 0.60–0.61, high cigarette/low e-cigarette: aRRR = 0.74; 95% CI: 0.73–0.74, and low cigarette/high e-cigarette: aRRR = 0.72; 95% CI: 0.71–0.73).

Conclusions: Enforcing existing tobacco control measures likely interacts with e-cigarette use despite being cigarette-focused. Continuing to monitor e-cigarette use is critical to establish baseline use and evaluate future e-cigarette specific federal and state-level tobacco regulatory actions while accounting for the existing tobacco control environment.

Implications: This study investigates state-level current use estimates of e-cigarettes and cigarettes among US adults; and their association with four existing tobacco control measures. The overall score of these measures was negatively associated with state-level current use estimates such that states with low current e-cigarette and cigarette use had the highest mean overall score. This study assesses the potential relationship between existing state-level tobacco control measures and e-cigarette use and calls for improving the enforcement of the known-to-work tobacco control measures across all US states, while developing evidence-based regulations and interventions specific to e-cigarettes within the existing US tobacco use environment.

Introduction

Globally, comprehensive tobacco control efforts have slowed the epidemic of tobacco use by enforcing an array of policies and regulations,¹ which are the result of decades of research on the multiple adverse effects of tobacco use, social and behavioral characteristics associated with tobacco use, and assiduous implementation and evaluation of the impact of such policies. However, tobacco control policies and research are primarily limited to conventional cigarette smoking.^{1,2} In recent years, the use of a wide range of new nicotine delivery products, such as electronic cigarettes (e-cigarettes), has started to thrive,^{3,4} threatening current tobacco control achievements.^{5,6}

E-cigarettes are battery-powered devices that convert nicotine-containing liquid into a vapor that can be inhaled.⁷ In the United States, e-cigarette use has been rapidly increasing among both smokers and nonsmokers alike.^{8–13} Nevertheless, some studies suggest that e-cigarette use can cause adverse health effects,^{14–16} and that some brands of the liquid nicotine used in e-cigarettes contain toxicants and carcinogens similar to those found in traditional cigarettes.^{17–21} On the other hand, preliminary evidence suggests that e-cigarettes could be beneficial for harm reduction or as a smoking cessation aid.^{9,22}

The number of e-cigarette brands available in the US market increased from 250 to 460 within a limited period of time (May 2012–January 2014).^{23,24} This rapid evolution of the e-cigarette market and a diverse variability between products has established barriers to generating the needed evidence for developing targeted regulations.^{23–26} Although, the recently issued e-cigarettes’ “deeming rule” provides a platform for future federal-level regulatory actions,^{27–30} US states can enforce their local policies and regulations.^{31,32} Of particular interest, there is an ongoing debate on how existing tobacco control measures and policies are interacting with e-cigarette use,^{5,33–35} especially with limited existing e-cigarette specific policies, which has been primarily limited to restricting youth access, as of 2014.³⁶ Existing community-level tobacco control measures take the form of state-level tobacco control programs, and we have limited knowledge of the ways in which the existing tobacco control environment is interacting with e-cigarette use.³⁵ Moreover, our knowledge is very limited regarding the state-level differences of e-cigarette use patterns compared to cigarette smoking. To address this gap, it would be beneficial to understand state-level differences in use of e-cigarettes, as well as cigarettes, within the existing tobacco control framework. This will allow researchers to better track state-level differences of their use and the eventual impact of yet-to-be implemented national and state-level e-cigarette control measures.

Therefore, in order to enhance our understanding of the emerging e-cigarette epidemic in the United States, the present study used 2012–2013 and 2013–2014 data from the National Adult Tobacco

Survey (NATS), as well as the American Lung Association’s State of Tobacco Control (SOTC) report for 2012 and 2013 to assess the state-specific prevalence estimates of cigarettes and e-cigarette use, and to determine their relationship with existing state-level tobacco control measures, while accounting for respondents’ socio-demographic characteristics. We hypothesized that overall effective implementation of tobacco control measures at the state-level, reflecting higher TCI scores, will be associated with lower estimates for both cigarette and e-cigarette use at the state-level.

Methods

Study Population

Data from the 2012–2013 and 2013–2014 NATS were used. These are the first years for which questions regarding e-cigarettes were included. We merged the NATS data for 2012–2013 and 2013–2014 waves to obtain the overall estimates presented in the study covering the period of 2012–2014. We matched corresponding state-level tobacco control measures from the SOTC for years 2012 and 2013 with the 2012–2013 and 2013–2014 waves, respectively. As the NATS and SOTC are publicly available, the current study was exempt from institutional review board approval. All 50 US states and the District of Columbia were included in the analyses.

Details of the NATS design and methodologies are available elsewhere.^{37,38} Briefly, NATS was designed as a stratified, national telephone survey of US non-institutionalized adults (aged 18 years and older) residing in the 50 states and the District of Columbia; respondents were selected by random digit dialing. The sample design for NATS had specific semi-proportional goals by state and by sample frame. The state goals of the 2012–2013 NATS targeted a minimum of 800 completed surveys per state: 600 landline (75%) and 200 cell-only (25%) from each state. The top 20 most populous states with goals above 800 accounted for the remaining 36 000 surveys allocated across these states in approximate proportion to their population.³⁷ For the 2013–2014 NATS, each state and the overall sample goals included 30% cell-only households and 70% landline households (regardless of whether they also had a cell phone). The state goals of the 2013–2014 NATS wave included a minimum of 1000 combined completed surveys per state: 700 landline (70%) and 300 cell-only (30%). The 20 most populous states had goals above 1000 interviews, with the remaining 44 000 completed surveys distributed across these states in approximate proportion to their populations.³⁸ The samples of each frame were also disproportionately stratified by state to ensure adequate representation of each state, along with higher numbers of completed surveys from states with larger populations. The response rates of the NATS surveys were as follows: 2012–2013, total 44.9% with the response rate for landline being 47.2% and for cellular 36.3%; and 2013–2014, total 36.1%, landline 47.6%, cellular, 17.1%.^{37,38}

The Tobacco Control Index

The American Lung Association's SOTC report evaluates state tobacco control policies and measures by comparing them against targets based on the most current, recognized criteria for effective tobacco control. The Report includes four state-level tobacco control measures: smoke free air laws, cessation coverage, tobacco control spending, and cigarette excise tax. Two of those measures are based on a scoring system that includes an evaluation of their relevant components. Specifically, the "smoke-free air policy score" is based on the availability of such policies for different types of facilities (eg, Government and private worksite, bars, restaurants, schools), as well as enforcement of these policies. The "cessation coverage score" is based on several metrics including the availability of cessation medications, and cessation counseling for state Medicaid health program and state employee health plans, as well as state quitline investment per smoker. The other two measures are based on actual values: the "state-level cigarette excise tax" in US dollars, and the percentage of the Centers of Disease Control's recommended "state-level funding for tobacco prevention and control programs spending". Further details of the SOTC reports are available elsewhere.³⁹ The authors used the aforementioned state-level tobacco control measures found in the SOTC to calculate the Tobacco Control Index (TCI) as an overall *proxy* indicator for evaluating the implementation of a comprehensive set of tobacco control measures in each state.

The authors created the TCI following standard best practice in calculating similar indices.^{40–42} First, z-scores (ie, standardized values) for each of the four tobacco control measures were calculated. The state-level z-score for each measure was then summed up to generate an overall standardized TCI score for each state. In order to test the robustness of the TCI, the authors examined the independent correlation of the each of the four measures, as well as the overall TCI, with state-level smoking attributable death per 100 000 population, which were also published in the SOTC reports. The authors found all the four measures, as well as the TCI to be significantly negatively correlated with state-level smoking attributable deaths. Pearson correlation coefficient was -0.22 ($p = .038$) for tobacco control spending, -0.25 ($p = .011$) for cessation coverage, -0.27 for smoke free air laws ($p = .006$), -0.45 for cigarette excise tax ($p < .001$), and -0.46 ($p < .001$) for TCI.

E-cigarette and Cigarette Use Variables

Using the NATS, respondents who answered "yes" to the question, "Before today, had you ever heard of electronic cigarettes or e-cigarettes?" were defined as being aware of e-cigarettes. Current users of e-cigarettes were identified as those NATS-respondents who selected "everyday," "some days," or "rarely" in response to the question "Do you now smoke tobacco in an e-cigarette every day, some days, rarely, or not at all?". Ever-users of e-cigarettes were those who answered "yes" to the question, "Have you ever smoked tobacco in an e-cigarette in your entire life?". Participants were identified to be current cigarette smokers if they answered "yes" to the question, "Have you smoked at least 100 cigarettes in your entire life?" and responded with "every day," or "some days," to the question, "Do you now smoke cigarettes every day, some days, or not at all?".

Other Variables

We included a number of socio-demographic variables in the current study. Gender (male and female) was included. For age, we included the following categories: 18–24, 25–34, 35–44, 45–54, 55–64, and ≥ 65 . For race/ethnicity, our categories were non-Hispanic white,

non-Hispanic black, non-Hispanic Asian, Hispanic, and non-Hispanic other. Educational attainment was categorized into less than high school diploma, high school graduate, some college or associate degree, bachelor's degree or higher. The cut-off points for annual household income were $< \$20\,000$, $\$20\,000$ – $\$49\,999$, $\$50\,000$ – $\$99\,999$, $\geq \$100\,000$. Marital status was dichotomized into married/living with a partner, and single/divorced/widowed/separated.

State Categories for Combined Cigarette and E-cigarette Current Use

We categorized states as high or low on the current use estimate for each product based on whether they were above or below the mean state estimate of 5.56% for current e-cigarette and 18.17% for current cigarette use. Following that, we generated four US-state categories (low cigarettes/e-cigarettes, high cigarette/low e-cigarette, low cigarette/high e-cigarette, and high cigarette/ e-cigarette) based on the combined current use estimates of each product for the 50 states and the District of Columbia (eg, Georgia was categorized as high use state for cigarettes but was also categorized as low use state for e-cigarettes, thus it was assigned to the high cigarette/low e-cigarette state category).

Statistical Analyses

For this study, data from the 2012–2013 and 2013–2014 NATS were merged ($n = 135\,425$) and analyzed in 2017. Because the NATS is a nationally representative survey that employs a stratified, multi-stage sampling design, statistical analyses were performed using the "survey" module of Stata 14.0 (StataCorp, College Station, TX) to account for the complex sample design and responses. Each sampling frame's data were weighted differently. Landline data were weighted by the following items: probability of selection of a respondent's telephone number, nonresponse, number of landlines in the household, and number of adults in the household, while cell phone data were only weighted to adjust for probability of selection and nonresponse. Final weights were determined using a raking method (which included state, age, gender, race/ethnicity, marital status, educational attainment, and phone category) to adjust for under-coverage and nonresponse bias.⁴³ For GIS mapping, the ArcGIS 10.3 (ESRI, Redlands, CA) software was used.

The TCI score was merged into the dataset. E-cigarette awareness, lifetime and current e-cigarette and cigarette use estimates were calculated for each state. Weighted percentages and confidence intervals were used for descriptive analysis. The independent association between the TCI and socio-demographic characteristics and current cigarette and e-cigarette use was assessed at the state-level by grouping states into four categories, as previously described. We conducted multinomial logistic regression with the US-state category of low cigarettes/e-cigarettes as the reference group and represented our findings using adjusted Relative Risk Ratio (aRRR). The present study used a significance level of $\alpha = 0.05$.

Results

Among US adults surveyed between 2012 and 2014 ($N = 135\,425$), over three-quarters (85.1%, $n = 114\,990$) reported ever hearing about e-cigarettes, 16.3% ($n = 16\,007$) reported ever using e-cigarettes at least once in their lifetime, current e-cigarette use estimate was 5.4% ($n = 5\,312$), and current traditional cigarette use estimate was 17.4% ($n = 18\,134$). Table 1 presents state-level estimates of

Table 1. Estimates^a of E-cigarette Awareness, Ever Use and Current Use, and Combustible Cigarettes Current Smoking Among US Adults Aged ≥18Years, by Combined Cigarette and E-cigarette State Categories: National Adult Tobacco Survey Waves 2012–2013 and 2013–2014 (N = 135 425)

	Total (N ^b)	E-cigarette awareness ^c	E-cigarette ever used ^d	E-cigarette current ^e	Cigarette current ^f
		n = 114 990	n = 16 007	n = 5 312	n = 18 134
Nationwide ^b					
High cigarette/e-cigarette states					
Alabama	1847	86.8 (84.9, 88.6)	17.8 (15.4, 20.4)	7.0 (5.5, 8.9)	22.1 (19.5, 25.0)
Arkansas	1777	86.9 (84.7, 88.8)	22.2 (19.5, 25.2)	6.8 (5.2, 8.9)	23.5 (20.7, 26.5)
Indiana	2237	89.1 (87.5, 90.5)	17.7 (15.6, 19.9)	5.9 (4.7, 7.4)	20.3 (18.2, 22.6)
Iowa	1795	87.5 (85.6, 89.1)	15.0 (12.8, 17.5)	5.9 (4.5, 7.6)	18.4 (16.1, 21.1)
Kansas	1769	88.1 (86.0, 89.9)	18.4 (15.9, 21.2)	6.2 (4.8, 7.9)	18.3 (15.8, 21.0)
Kentucky	1786	88.9 (86.8, 90.8)	20.7 (18.1, 23.4)	7.4 (5.9, 9.2)	23.4 (20.8, 26.3)
Louisiana	1819	85.7 (83.4, 87.7)	17.6 (15.2, 20.4)	6.1 (4.6, 8.0)	21.6 (18.9, 24.6)
Missouri	2055	91.2 (89.6, 92.6)	19.7 (17.4, 22.2)	5.6 (4.4, 7.0)	22.6 (20.2, 25.2)
Nevada	1799	86.4 (83.9, 88.5)	21.2 (18.6, 24.0)	7.4 (5.8, 9.3)	18.9 (16.5, 21.5)
New Mexico	1798	84.6 (82.1, 86.8)	21.6 (18.8, 24.6)	8.7 (6.8, 11.0)	19.7 (17.1, 22.6)
North Carolina	3346	85.6 (84.1, 87.0)	17.1 (15.4, 19.0)	5.8 (4.7, 7.1)	19.8 (18.0, 21.8)
North Dakota	1775	88.8 (86.8, 90.6)	17.3 (14.7, 20.4)	5.7 (4.2, 7.6)	22.2 (19.2, 25.6)
Ohio	3885	88.1 (86.7, 89.3)	17.8 (16.2, 19.6)	6.3 (5.3, 7.5)	19.6 (17.9, 21.4)
Oklahoma	1787	89.6 (87.6, 91.2)	25.5 (22.9, 28.3)	10.3 (8.5, 12.4)	23.1 (20.6, 25.9)
Tennessee	2187	87.8 (86.0, 89.4)	18.2 (16.0, 20.7)	6.1 (4.8, 7.8)	23.2 (20.7, 25.9)
Wyoming	1733	89.9 (87.7, 91.7)	20.5 (17.5, 23.8)	8.6 (6.6, 11.2)	21.0 (17.6, 25.0)
High cigarette/ low e-cigarette states					
Georgia	3439	83.1 (81.4, 84.7)	15.6 (13.9, 17.4)	5.0 (4.1, 6.1)	19.1 (17.3, 21.1)
Illinois	4371	85.3 (83.7, 86.7)	16.5 (14.9, 18.2)	4.9 (4.1, 6.0)	18.7 (17.1, 20.5)
Maine	1738	86.2 (84.1, 88.0)	13.6 (11.7, 15.9)	3.8 (2.8, 5.1)	18.4 (16.1, 21.0)
Michigan	3419	88.1 (86.6, 89.4)	16.8 (15.1, 18.6)	5.5 (4.5, 6.7)	18.8 (17.0, 20.6)
Mississippi	1798	82.1 (79.7, 84.3)	15.7 (13.2, 18.4)	5.0 (3.6, 6.9)	23.4 (20.5, 26.5)
Montana	1754	87.3 (85.1, 89.2)	17.0 (14.7, 19.5)	5.0 (3.8, 6.5)	18.3 (16.0, 20.9)
Pennsylvania	4302	86.7 (85.4, 87.8)	15.3 (13.9, 16.8)	4.5 (3.7, 5.5)	19.5 (18.0, 21.2)
South Carolina	1799	85.6 (83.3, 87.6)	16.4 (14.2, 19.0)	4.2 (3.2, 5.6)	21.5 (18.8, 24.5)
South Dakota	1748	83.9 (80.3, 86.9)	13.2 (11.0, 15.7)	3.8 (2.6, 5.6)	19.0 (16.1, 22.2)
West Virginia	1741	88.7 (86.9, 90.3)	19.1 (16.7, 21.8)	5.3 (4.0, 7.0)	26.1 (23.4, 29.0)
Wisconsin	1943	87.3 (85.3, 89.0)	15.1 (13.1, 17.4)	4.1 (3.1, 5.4)	18.7 (16.4, 21.2)
Low cigarette/high e-cigarette states					
Alaska	1765	89.3 (87.4, 91.0)	19.7 (17.0, 22.8)	7.2 (5.4, 9.6)	17.0 (14.6, 19.6)
Arizona	2316	86.4 (84.4, 88.2)	18.9 (16.7, 21.3)	6.7 (5.4, 8.4)	16.6 (14.5, 18.9)
Colorado	1916	86.8 (84.6, 88.7)	14.6 (12.5, 16.9)	6.0 (4.5, 7.8)	15.8 (13.5, 18.3)
Hawaii	1735	88.9 (86.8, 90.8)	18.5 (15.8, 21.6)	7.6 (5.8, 9.9)	14.6 (12.2, 17.4)
Idaho	1797	89.6 (87.7, 91.2)	18.0 (15.6, 20.6)	6.6 (5.2, 8.5)	15.4 (13.1, 18.0)
Minnesota	1895	86.6 (84.5, 88.4)	14.8 (12.8, 17.2)	6.5 (5.2, 8.2)	16.7 (14.5, 19.2)
Nebraska	1788	86.2 (84.1, 88.1)	16.6 (14.3, 19.2)	6.4 (4.9, 8.3)	16.9 (14.6, 19.5)
Texas	8551	82.8 (81.6, 84.0)	17.2 (16.1, 18.4)	6.0 (5.3, 6.8)	16.9 (15.7, 18.0)
Utah	1804	85.0 (82.6, 87.2)	14.9 (12.6, 17.4)	6.2 (4.7, 8.1)	10.7 (8.8, 12.9)
Low cigarettes/e-cigarettes states					
California	12 761	79.1 (78.0, 80.1)	15.3 (14.4, 16.3)	5.0 (4.5, 5.6)	12.9 (12.1, 13.8)
Connecticut	1732	85.1 (82.8, 87.2)	13.6 (11.5, 16.1)	3.2 (2.3, 4.6)	15.4 (13.2, 18.0)
Delaware	1744	82.4 (79.9, 84.7)	10.3 (8.4, 12.6)	2.7 (1.8, 4.0)	14.6 (12.5, 17.1)
District of Columbia	1523	80.9 (77.4, 83.9)	11.8 (8.7, 15.6)	4.6 (2.4, 8.7)	17.6 (14.3, 21.6)
Florida	6438	85.2 (83.9, 86.4)	17.1 (15.8, 18.5)	5.3 (4.5, 6.1)	17.2 (15.9, 18.6)
Maryland	2077	84.2 (82.1, 86.2)	11.4 (9.7, 13.4)	3.7 (2.7, 5.2)	14.6 (12.6, 16.9)
Massachusetts	2362	84.8 (82.6, 86.7)	12.5 (10.5, 14.9)	3.7 (2.6, 5.2)	14.1 (12.0, 16.5)
New Hampshire	1706	88.9 (86.9, 90.6)	13.4 (11.2, 16.0)	3.6 (2.4, 5.3)	16.1 (13.7, 18.9)
New Jersey	2852	82.4 (80.2, 84.4)	13.5 (11.7, 15.5)	4.0 (3.0, 5.3)	12.7 (11.0, 14.6)
New York	6550	83.5 (82.2, 84.8)	14.0 (12.8, 15.2)	4.6 (3.9, 5.3)	15.4 (14.2, 16.7)
Oregon	1893	89.2 (87.3, 90.8)	15.4 (13.3, 17.8)	4.7 (3.5, 6.1)	16.5 (14.3, 18.9)
Rhode Island	1733	85.5 (83.2, 87.5)	13.5 (11.2, 16.1)	4.2 (2.9, 6.1)	15.4 (13.1, 18.0)
Vermont	1698	87.2 (85.1, 89.1)	12.0 (9.9, 14.5)	3.9 (2.8, 5.4)	12.6 (10.5, 15.1)
Virginia	2868	87.3 (85.8, 88.8)	14.8 (13.1, 16.6)	5.4 (4.4, 6.7)	17.0 (15.1, 19.0)
Washington	2474	88.2 (86.6, 89.7)	15.3 (13.6, 17.3)	4.6 (3.6, 5.7)	14.8 (13.1, 16.8)

^aValues are weighted percentage, with 95% confidence intervals calculated by Taylor series linearization to account for the complex survey design.^bUnweighted sample sizes with weighted percentages displayed in parentheses.^cRespondents who reported “yes” to the question, “Before today, had you ever heard of electronic cigarettes or e-cigarettes?”^dRespondents who responded “yes” to the question, “Have you ever used an electronic cigarette, even just one time in your entire life” were defined as having ever used an electronic cigarette.^eRespondents who reported using electronic cigarettes “everyday,” “some days” or “rarely” were defined as current users of e-cigarettes.^fRespondents who reported smoking at least 100 cigarettes during their lifetime and now smoked “every day” or “some days” were defined as current cigarettes smokers.

awareness, ever use (ie, lifetime use) and current use of e-cigarettes, as well as current use of traditional cigarettes among US adults. Considering awareness of e-cigarettes as the denominator (ie, those who have reported ever hearing about e-cigarettes), 19.1% reported lifetime use. One-third (33.1%) of ever e-cigarette users reported current e-cigarettes use either *every day* (19.3%, $n = 1118$), *some days* (29.3%, $n = 1574$), or *rarely* (51.5%, $n = 2620$). State-level estimates of e-cigarette awareness ranged from 79.1% (95% CI: 89.6–92.6) in Missouri to 91.2% (95% CI: 89.6–92.6) in California. As for e-cigarette use, state-level estimates of lifetime use ranged from 10.3% (95% CI: 8.4–12.6) in Delaware to 25.5% (95% CI: 22.9–28.3) in Oklahoma, and current use estimates ranged from 2.7% (95% CI: 1.8–4.0) in Delaware to 10.3% (95% CI: 8.5–12.4) in Oklahoma. Finally, state-level current cigarette use estimates ranged from 10.7% (95% CI: 8.8–12.9) in Utah to 26.1% (95% CI: 23.4–29.0) in West Virginia.

Awareness of e-cigarettes had limited variation across all US states (range: 79.1–91.2%). The distributions of the prevalence estimates of lifetime and current e-cigarette use appeared to be similar. For lifetime and current e-cigarette use, mostly western and southern states tended to have higher rates, while eastern states tended to have lower ones. Fourteen states had rates of lifetime e-cigarette use greater than or equal to 18%: Alaska, Arizona, Arkansas, Hawaii, Idaho, Kansas, Kentucky, Missouri, Nevada, New Mexico, Oklahoma, Tennessee, West Virginia, and Wyoming. We present the weighted percentage

of current e-cigarette use by state in Figure 1, with darker shading indicating a higher prevalence of e-cigarette use. Classifications are based on quintiles. Twenty states had rates of current e-cigarette use equal or greater than 6%: Alabama, Alaska, Arizona, Arkansas, Colorado, Hawaii, Idaho, Kansas, Kentucky, Louisiana, Minnesota, Nebraska, Nevada, New Mexico, Ohio, Oklahoma, Tennessee, Texas, Utah and Wyoming.

The overall TCI ranged from -7.12 to 5.63 (mean = 0.16 , $SD = \pm 2.35$). Based on the mean values for current e-cigarette and cigarette use estimates, the four US state categories (Table 1) by overall use of both products were (1) *low cigarette/e-cigarette* ($n = 15$; TCI ranged from -0.80 to 4.62 , mean = 0.64 , $SD = \pm 1.92$); (2) *high cigarette/e-cigarette* ($n = 16$, TCI ranged from -7.12 to 3.35 , mean = -1.03 , $SD = \pm 2.43$); (3) *high cigarette/low e-cigarette* ($n = 11$; TCI ranged from -4.44 to 4.96 , mean = -0.48 , $SD = \pm 2.30$); and (4) *low cigarette/high e-cigarette* ($n = 9$; TCI ranged from -3.90 to 5.63 , mean = -0.28 , $SD = \pm 2.56$). Figure 2 shows the four state categories of cigarette and e-cigarette use.

The multinomial logistic regression model findings are presented in Table 2. Significant differences were observed regarding the TCI scores across the four groups, after adjusting for age, gender and marital status distribution, race/ethnicity composition, education and household income levels within all states. States in the high cigarette/e-cigarette category, as compared with low cigarette/e-cigarette category, were associated with lower TCI score (aRRR = 0.61 ;

Figure 1. State-specific weighted estimates of e-cigarette current use among adults in the United States: National Adult Tobacco Survey, 2012–2014.

Figure 2. State categories of combined e-cigarette and cigarette current use among adults in the United States: National Adult Tobacco Survey, 2012–2014.

95% CI = 0.60–0.61). Moreover, states in the high cigarette/low e-cigarette category and low cigarette/high e-cigarette category were associated with having lower TCI scores compared with states in the low cigarette/e-cigarette category (aRRR = 0.74; 95% CI = 0.73–0.74, aRRR = 0.72; 95% CI = 0.71–0.73, respectively). Several significant differences were observed among the sociodemographic characteristics across the four state categories, which are presented in Table 2.

Discussion

This study examines existing state-level tobacco control measures in the United States and their relationship with the combined cigarette and e-cigarette current use prevalence estimates for each state. While controlling for individual-level sociodemographic factors, states in the high cigarette/e-cigarette use category, high cigarette/low e-cigarette, and low cigarette/high e-cigarette categories were associated with having lower TCI scores as compared to states in the low cigarette/e-cigarette category, likely reflecting more overall comprehensive implementation of the tobacco control measures among the states in the low cigarette/e-cigarette category. However, the socio-demographic compositions for the US state categories seemed to play an important role suggesting that the overall effect of the included tobacco control measures on the state level prevalence

estimates of e-cigarettes and cigarettes may vary depending on the sociodemographic composition within each state.

E-cigarette Awareness and State-Level Use Patterns

The estimates of current e-cigarette use from the present study (5.4%) were not substantially higher than the results of the National Health Interview Survey (2012–2013), which estimated current e-cigarette prevalence at 4.1%.⁴⁴ Nevertheless, awareness varied slightly by state within the 80% to 90% range. As not all adults in the United States were aware of e-cigarettes, it could be argued that with the rapidly expanding marketing and advertising efforts of e-cigarette companies,^{10,45} more adults will become aware of e-cigarettes. Subsequently, life time use prevalence, as well as current e-cigarettes use, could continue to grow with the expanding e-cigarette marketing efforts to perhaps approximate the prevalence estimates of e-cigarette use among those who are aware of the product (eg, life-time use among the total US population was estimated to be 16.3%, vs. 19.1% when we account for e-cigarette use among those with e-cigarette awareness).

Despite the limited variation among states in terms of awareness and lifetime use of e-cigarettes, its current use reflected a much larger variation across states, such that the state with the highest estimate (Oklahoma) reporting current use of almost four times higher than the state with the lowest estimate (Delaware). Furthermore,

Table 2. Estimates and Adjusted Model of the Factors Associated With Combined Cigarette and E-cigarette State Categories: National Adult Tobacco Survey Waves 2012–2013 and 2013–2014 (N = 135 425)^a

	Low cigarettes/e-cigarettes category ^b (n = 50 411)		High cigarette/e-cigarette category ^c (n = 33 395)		High cigarette/low e-cigarette category ^d (n = 28 052)		Low cigarette/high e-cigarette category ^e (n = 23 567)	
	% (95% CI) ^f	% (95% CI) ^f	% (95% CI) ^f	aRRR (95% CI) ^g	% (95% CI) ^f	aRRR (95% CI)	% (95% CI) ^f	aRRR (95% CI)
TCI ^h (mean, SD)	0.64 (±1.92)	–1.03 (±2.43)	0.61 (0.60, 0.61)**		–0.48 (±2.3)	0.74 (0.73, 0.74)**	–0.28 (±2.56)	0.72 (0.71, 0.73)**
Age group								
18–24	39.9 (38.6, 41.3)	22.9 (21.8, 24.0)	Referent		20.1 (19.0, 21.2)	Referent	17.1 (16.1, 18.1)	Referent
25–34	40.6 (39.5, 41.6)	22.7 (21.9, 23.6)	0.92 (0.82, 1.03)		19.4 (18.6, 20.3)	0.89 (0.78, 1.00)*	17.3 (16.5, 18.1)	0.89 (0.79, 1.06)
35–44	40.6 (39.6, 41.7)	22.7 (21.9, 23.5)	0.96 (0.86, 1.08)		19.9 (19.1, 20.7)	0.83 (0.84, 1.06)	16.8 (16.0, 17.6)	0.93 (0.83, 1.05)
45–54	40.5 (39.6, 41.4)	23.1 (22.3, 23.8)	0.85 (0.82, 0.96)*		20.9 (20.2, 21.6)	0.86 (0.77, 0.96)*	15.5 (14.9, 16.2)	0.82 (0.73, 0.92)**
55–64	39.8 (39.9, 40.5)	23.9 (23.3, 24.6)	0.79 (0.71, 0.88)**		21.3 (20.7, 21.9)	0.81 (0.73, 0.90)**	15.1 (14.6, 15.6)	0.81 (0.72, 0.90)**
≥65	40.8 (40.2, 41.4)	23.9 (23.4, 24.4)	0.67 (0.61, 0.75)**		21.0 (20.5, 21.5)	0.69 (0.62, 0.77)**	14.4 (14.0, 14.8)	0.74 (0.67, 0.82)**
Gender								
Male	40.5 (39.9, 41.1)	23.1 (22.6, 23.6)	1.05 (1.00, 1.10)*		20.3 (19.8, 20.7)	1.04 (0.99, 1.09)	16.2 (15.8, 16.6)	1.06 (1.00, 1.11)*
Female	40.5 (40.0, 41.1)	23.2 (22.8, 23.6)	Referent		20.5 (20.1, 20.9)	Referent	15.8 (15.4, 16.1)	Referent
Race/ethnicity								
NH-white	35.9 (35.5, 36.3)	26.7 (26.4, 27.1)	Referent		22.7 (22.3, 23.1)	Referent	14.7 (14.4, 15.0)	Referent
NH-black	37.1 (35.8, 38.3)	25.9 (24.8, 27.0)	0.62 (0.57, 0.68)**		27.1 (25.9, 28.3)	0.91 (0.83, 0.98)*	9.9 (9.2, 10.7)	0.54 (0.48, 0.60)**
NH-Asian	70.6 (68.7, 72.5)	5.7 (5.0, 6.5)	0.12 (0.10, 0.14)**		10.2 (9.0, 11.5)	0.22 (0.18, 0.26)**	13.5 (12.3, 14.8)	0.44 (0.38, 0.51)**
Hispanic	55.2 (53.9, 56.5)	9.7 (9.1, 10.3)	0.16 (0.14, 0.17)**		8.9 (8.2, 9.7)	0.18 (0.16, 0.20)**	26.2 (25.1, 27.4)	0.94 (0.87, 1.01)
NH-Other	45.0 (43.2, 46.8)	21.8 (20.6, 23.1)	0.59 (0.53, 0.66)**		15.8 (14.6, 17.0)	0.50 (0.44, 0.57)**	17.4 (16.2, 18.7)	0.92 (0.81, 1.04)
Education								
<High school diploma	41.5 (40.1, 42.9)	23.1 (22.1, 24.2)	Referent		18.5 (17.4, 19.5)	Referent	16.9 (15.9, 18.0)	Referent
High school graduate	37.0 (36.2, 37.8)	26.1 (25.4, 26.8)	1.01 (0.91, 1.12)		22.5 (21.8, 23.1)	1.06 (0.95, 1.19)	14.5 (14.0, 15.0)	1.04 (0.92, 1.16)
Some college/associate degree	39.2 (38.5, 39.9)	23.5 (23.0, 24.1)	0.88 (0.80, 0.98)**		20.2 (19.7, 20.8)	0.86 (0.82, 1.02)	17.1 (16.6, 17.6)	1.2 (1.08, 1.36)**
≥Bachelor degree	45.0 (44.5, 45.6)	19.8 (19.4, 20.2)	0.76 (0.69, 0.84)**		19.5 (19.0, 19.9)	0.86 (0.77, 0.97)**	15.7 (15.3, 16.1)	1.06 (0.95, 1.19)
Annual household income								
<20 000	37.2 (35.9, 38.5)	26.3 (25.2, 27.4)	Referent		21.1 (20.0, 22.1)	Referent	15.5 (14.6, 16.5)	Referent
20 000–49 999	37.0 (36.3, 37.8)	25.5 (24.8, 26.1)	0.88 (0.81, 0.96)*		20.9 (20.3, 21.6)	0.91 (0.83, 0.99)*	16.6 (16.0, 17.2)	1.01 (0.92, 1.12)
50 000–99 999	38.4 (37.7, 39.2)	23.7 (23.0, 24.3)	0.69 (0.63, 0.76)**		21.5 (20.9, 22.1)	0.80 (0.72, 0.88)**	16.5 (15.9, 17.0)	0.93 (0.80, 1.03)
≥100 000	47.8 (46.9, 48.6)	18.6 (18.0, 19.3)	0.41 (0.37, 0.45)**		18.1 (17.5, 18.7)	0.51 (0.46, 0.56)**	15.5 (14.9, 16.1)	0.67 (0.61, 0.75)**
Marital status								
Married/ with a partner	39.9 (39.5, 40.4)	23.3 (22.9, 23.7)	Referent		20.2 (19.8, 20.6)	Referent	16.6 (16.2, 17.0)	Referent
Single/divorced/widowed/separated	41.3 (40.7, 41.9)	22.8 (22.4, 23.8)	0.81 (0.76, 0.85)**		20.6 (20.2, 21.2)	0.88 (0.83, 0.93)**	15.2 (14.7, 15.6)	0.85 (0.80, 0.90)**

TCI = Tobacco Control Index; SD = standard deviation; CI = confidence interval; aRRR = adjusted relative risk ratio; NH = non-Hispanic.

^aUnweighted n for individuals in each group.^bLow cigarettes and e-cigarettes category is the reference group for the multivariate logistic regression model. Low cigarettes and e-cigarettes category includes California, Connecticut, Delaware, District of Columbia, Florida, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Oregon, Rhode Island, Vermont, Virginia, and Washington.^cHigh cigarette and e-cigarette category includes Alabama, Arkansas, Indiana, Iowa, Kansas, Kentucky, Louisiana, Missouri, Nevada, New Mexico, North Carolina, North Dakota, Ohio, Oklahoma, Tennessee, and Wyoming.^dHigh cigarette and low e-cigarette category includes Georgia, Illinois, Maine, Michigan, Mississippi, Montana, Pennsylvania, South Carolina, South Dakota, West Virginia, and Wisconsin.^eLow cigarette and high e-cigarette category includes Alaska, Arizona, Colorado, Hawaii, Idaho, Minnesota, Nebraska, Nebraska, Texas, and Utah.^fValues are weighted percentage, with 95% CIs calculated by Taylor series linearization to account for the complex survey design for all covariates except for the TCI where we present mean and SD values.^gTobacco control evaluation index (TCI) is compiled by summing up the z-scores of four state-level tobacco control measures: tobacco control spending, cessation coverage, smoke free air laws, and cigarette excise tax.^h*p < .05; **p < .001.

comparing the overall current prevalence estimates of cigarettes and e-cigarettes revealed that current cigarette use ranged from being roughly twice that of e-cigarettes (1.7) in Utah to being five times that of e-cigarettes (5.3) in Delaware. These findings suggest that diffusion of current e-cigarette use is taking place in varying degrees among different states and that vaping innovation may differ by geographic or state-level determinants.⁴⁶ There could be un-measured or un-identified factors that contributes to this wide variability in current e-cigarette use estimates between states. Comparative qualitative studies that explores state-level determinants for e-cigarette use could help identify some of these factors.

Interaction of Existing Tobacco Control Environment With E-cigarettes

Consistently, evidence has demonstrated that tobacco control measures are more effective when applied as a comprehensive set compared to a single tobacco control measure, in the sense that the whole is greater than the sum of individual policies or interventions.^{1,47} Echoing the importance of existing anti-smoking social norms in the United States, the rapid spread of e-cigarettes created a concern for many scholars about possible renormalization of tobacco use,^{48,49} which may encourage nonsmokers to commence cigarette smoking.⁵⁰ Our findings show that the higher the level of tobacco control measures a state has, the more likely that the combined current cigarette and e-cigarette use at the state-level would be lower. The spread of e-cigarettes offers a unique, yet unprecedented challenge in tobacco control research, as the products are marketed both to smokers as a smoking cessation device and to nonsmokers as a non-harmful method of indulging in a novel vaping behavior,⁸⁻¹³ which could further its spread and perhaps use in the United States. While the e-cigarette debate is still ongoing, researchers and policymakers should continue to implement, and more importantly enforce, the tobacco control measures that are known to work, as our results demonstrate that improved tobacco control climate at the state level is associated with lower rates of both traditional cigarette and e-cigarette use.

The current study results are to be interpreted with caution. The TCI represents an overall proxy indicator of the state-level tobacco control environment; it did not account for all state-level tobacco control interventions and did not include evaluation of e-cigarette specific measures. Based on our findings, how the existing tobacco control environment specifically interacts with e-cigarette use is difficult to ascertain. Currently, our knowledge of the state-level differences of e-cigarette use patterns is developing, let alone the impact of any future e-cigarette control regulations or policies. For example, evidence from the US e-cigarette sales data³⁵ and from six European Union members suggests that e-cigarette sales are responsive to price changes,^{33,35} and that e-cigarettes could even be more price sensitive than traditional cigarettes.³³ This may not be applicable to the United States; Huang et al. (2014) found in their market analysis study that cigarette prices had no statistically significant relationship with e-cigarette sales.³⁵ However, there were no prior attempts to evaluate the association of cigarette excise taxes with e-cigarette use as part of the overall existing tobacco control environment. Some researchers suggest implementing a tax on e-cigarettes to curb the spike of new e-cigarette adopters, without exerting a financial barrier on a potentially less harmful product and vehicle for smoking cessation.²⁶ Finally, e-cigarette users in the United States have different sociodemographic characteristics from cigarette smokers; e-cigarette users are more likely to be young adults, with higher income

and higher levels of education^{51,52}; nonetheless, there are other recent reports which indicate that the sociodemographic characteristics associated with e-cigarette use could be changing.^{53,54} Our state-level findings were adjusted to the weighted sociodemographic characteristics of the residents of each state; large-scale modifications in these compositions, although less likely—for example, due to economic growth—could potentially influence our findings. On the other hand, this is a strength of our approach, since state-level tobacco control measures could be interacting differently within each state due to its residents' sociodemographic characteristics, which we accounted for in our analysis.

This study has a number of limitations deserving of mention. NATS data relied on self-report with no biochemical verification, thus there could be self-report and social desirability bias. Further, the cross-sectional nature of the study does not enable us to conclude that correlates of e-cigarette use are associated with the current observed use estimates to examine state-level trends of e-cigarette use. Moreover, current users of e-cigarettes might be transient and/or dual users, which might result in over- or under-estimation of the actual current e-cigarette use of US adults. This also challenges our ability to interpret the wide variability between reported state-level e-cigarette and conventional cigarette current use. Not accounting for dual use of e-cigarette and cigarette in our assessment could have potentially modified the results; however, this is unlikely since our main outcome is comparing state categories for combined use estimates of both products. Future assessments that monitor use over time can account for the actual current use of e-cigarettes and ascertain the differences between exclusive and non-exclusive e-cigarette users, which could better inform e-cigarette sensitive policies and interventions. The TCI included an assessment of existing tobacco control measures on the state-level and does not account for variability of within state measures (ie, more granular county/municipality level differences). Moreover, we only included four measures in constructing the TCI, which does not account for the whole array of recommended comprehensive tobacco control measures.¹

Despite the forthcoming federal regulations pertaining to e-cigarettes, several US states have already begun taking measures aimed at regulating them.^{36,55} Existing e-cigarette specific vape free air laws,³⁶ available in 12 states at the time of data collection, were not included in our evaluation of the state-level tobacco control environment. By 2014, 28 states had banned sales to minors;³⁶ however, we are not aware of any studies that assessed the enforcement of such laws and they were not likely to have impact upon our adult study population. Further, 12 states had specific laws that restricted indoor use of e-cigarettes;³⁶ whether these laws were enforced as well, is unknown.

Call for Action

There is limited state-level comparative research on other e-cigarette environment characteristics such as number of vape shops, variation in marketing and advertising with strong internet presence for e-cigarette companies, and comprehensive regulatory reports. For example, existing studies show a strong association between e-cigarette companies' marketing efforts near school and e-cigarette use prevalence among youth.⁵⁶ It is difficult to determine what factors may be contributing to the relatively marked increase in e-cigarette use in some states as compared to others. Comparative, yet state specific research is needed to identify such potential factors to be able to inform state specific interventions and policies. Monitoring e-cigarette use among US adults and the correlates of its diffusion is not only of critical importance for informing future regulatory actions

and behavioral interventions, but can also provide the baseline for assessing the impact of federal and state-level tobacco regulatory actions and effectiveness of future tobacco control programs. Most importantly, while it may take more time to create e-cigarette specific laws and regulations given their controversy, our study suggests that the tobacco control research community should continue to advocate for improved implementation of known-to-work comprehensive tobacco control measures that account for cigarette taxation, smoke free air, cessation services coverage and funding tobacco use prevention and cessation interventions at the state-level. In so doing, this could potentially contribute to a decline in state-level cigarette and e-cigarette current use.

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Declaration of Interests

None declared.

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