

# Revisiting the Rise of Electronic Nicotine Delivery Systems Using Search Query Surveillance

John W. Ayers, PhD, MA,<sup>1</sup> Benjamin M. Althouse, PhD, ScM,<sup>2,3</sup> Jon-Patrick Allem, PhD, MA,<sup>4</sup> Eric C. Leas, MPH,<sup>5</sup> Mark Dredze, PhD,<sup>6</sup> Rebecca S. Williams, PhD, MHS<sup>7,8</sup>

**Introduction:** Public perceptions of electronic nicotine delivery systems (ENDS) remain poorly understood because surveys are too costly to regularly implement and, when implemented, there are long delays between data collection and dissemination. Search query surveillance has bridged some of these gaps. Herein, ENDS' popularity in the U.S. is reassessed using Google searches.

**Methods:** ENDS searches originating in the U.S. from January 2009 through January 2015 were disaggregated by terms focused on e-cigarette (e.g., *e-cig*) versus vaping (e.g., *vapers*); their geolocation (e.g., state); the aggregate tobacco control measures corresponding to their geolocation (e.g., clean indoor air laws); and by terms that indicated the searcher's potential interest (e.g., *buy e-cigs* likely indicates shopping)—all analyzed in 2015.

**Results:** ENDS searches are rapidly increasing in the U.S., with 8,498,000 searches during 2014 alone. Increasingly, searches are shifting from e-cigarette- to vaping-focused terms, especially in coastal states and states where anti-smoking norms are stronger. For example, nationally, e-cigarette searches declined 9% (95% CI=1%, 16%) during 2014 compared with 2013, whereas vaping searches increased 136% (95% CI=97%, 186%), even surpassing e-cigarette searches. Additionally, the percentage of ENDS searches related to shopping (e.g., *vape shop*) nearly doubled in 2014, whereas searches related to health concerns (e.g., *vaping risks*) or cessation (e.g., *quit smoking with e-cigs*) were rare and declined in 2014.

**Conclusions:** ENDS popularity is rapidly growing and evolving. These findings could inform survey questionnaire development for follow-up investigation and immediately guide policy debates about how the public perceives the health risks or cessation benefits of ENDS.

(Am J Prev Med 2016;■(■):■■■-■■■) © 2016 Published by Elsevier Inc. on behalf of American Journal of Preventive Medicine

## Introduction

Electronic nicotine delivery systems (ENDS) are the first tobacco product born in the online age.<sup>1,2</sup> In 2011, Ayers and colleagues<sup>3</sup> found that Google

searches for ENDS in the U.S. were greater than searches for smoking alternatives or cessation devices. Nevertheless, snus was garnering more academic and media attention during this time.

These findings have been confirmed and expanded on by telephone surveys that find awareness and use of ENDS is increasing.<sup>4-10</sup> Yet, ENDS surveillance remains limited leaving the public health community unable to stay on top of potential changes in public perceptions of ENDS. For example, although nationally representative cross-sectional surveys of ENDS use are useful, they are often too costly to implement sub-annually and the evidence is often not revealed until long after the data are first collected. The result is that evidence gaps remain. For instance, little is known about how perceptions and interest around ENDS varies sub-nationally or changes over time.<sup>11</sup>

From the <sup>1</sup>Graduate School of Public Health, San Diego State University, San Diego, California; <sup>2</sup>The Santa Fe Institute, Santa Fe, New Mexico; <sup>3</sup>Department of Biology, New Mexico State University, Las Cruces, New Mexico; <sup>4</sup>Keck School of Medicine, University of Southern California, Los Angeles, California; <sup>5</sup>University of California San Diego School of Medicine, La Jolla, California; <sup>6</sup>Johns Hopkins Human Language Technology Center of Excellence, Baltimore, Maryland; <sup>7</sup>Lineberger Comprehensive Cancer Center, University of North Carolina, Chapel Hill, North Carolina; and <sup>8</sup>Center for Health Promotion and Disease Prevention, University of North Carolina, Chapel Hill, North Carolina

Address correspondence to: John W. Ayers, PhD, MA, San Diego State University, 9245 Sky Park Court, Suite 230, San Diego CA 92123. E-mail: ayers.john.w@gmail.com.

0749-3797/\$36.00

<http://dx.doi.org/10.1016/j.amepre.2015.12.008>

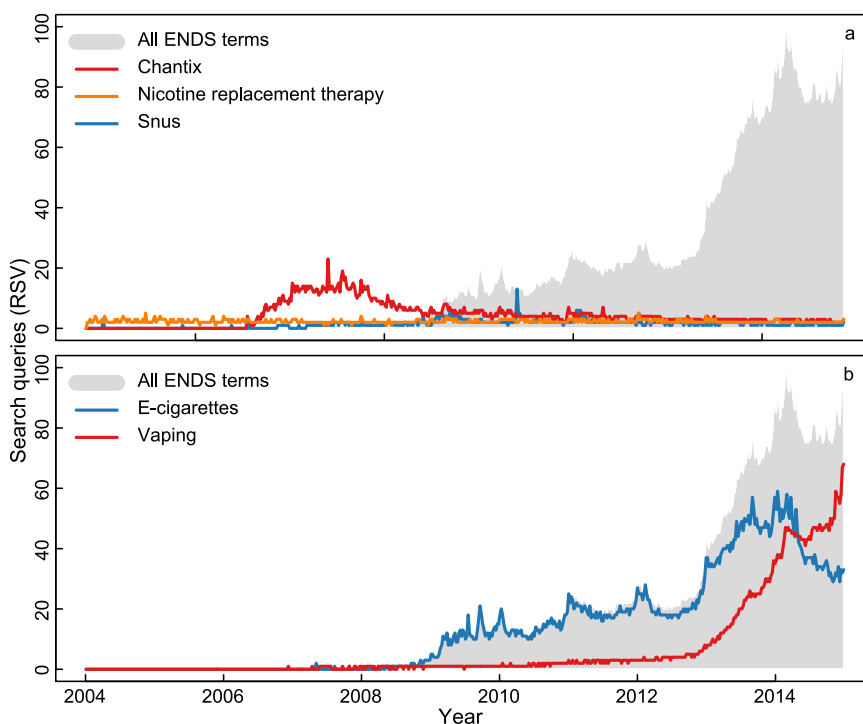
Continued analysis of Google search trends may fill some of these knowledge gaps and outline agendas for follow-up survey-based surveillance.<sup>12-15</sup> Examining the content of searches can reveal the searcher's thoughts and potential motivation for searching,<sup>16</sup> such as seeking information for purchasing ENDS, whether ENDS aid cessation, or if using ENDS pose any health risk. This study used exploratory analyses to assess variations in ENDS searches across states and time, including comparisons of searches across state-level tobacco control policies and social norms for cigarette smoking. Identifying ENDS search trends enhances the evidence base for the continued study of ENDS and their potential regulation.

## Methods

Weekly aggregated search query trends originating in the U.S. were analyzed from January 1, 2004, through January 1, 2015, using Google Trends ([google.com/trends](http://google.com/trends)). Google Trends is a publicly available index of search activity for specific search terms or categories of terms. Trends in searches are calculated by measuring the fraction of searches that include the terms (or categories) in question in a user-chosen geography at a particular time relative to the total number of searches at that time (relative search volume

[RSV]). The RSVs from Google Trends were supplemented by raw search volume derived from Google Adwords' search volume estimator ([adwords.google.com](http://adwords.google.com)). Hundreds of studies have used Google Trends for public health insights,<sup>17</sup> including several recent examples from the *American Journal of Preventive Medicine*.<sup>18-20</sup> Herein, all searches that included *ecig/s*, *e-cig/s*, *e cig/s*, *electronic cigarette/s*, *e cigarette/s*, or *e-cigarette/s* and *vape/s*, *vaper/s*, or *vaping* were monitored, after omitting searches that also mentioned *pot* or *weed*. For instance, this would include searches like *ecig*, *best ecig*, or *what are ecigs*?

Search query trends were described for the entire U.S. using the composite of all ENDS search terms and then stratified by those searches that included only e-cigarette (e.g., *ecig*, *electronic cigs*, and *e-cigarettes*) or only vaping (e.g., *vape*, *vaper*, and *vaping*) terms. Additionally, ENDS searches were compared to searches for snus, nicotine-replacement therapies, and Chantix, replicating methods detailed elsewhere.<sup>3</sup> All relied on trend analyses, enumerating changes in search volumes year over year and making projections through 2015 based on autoregressive integrated moving average models fit using the stepwise algorithm outlined by Hyndman and Khandakar.<sup>21</sup> Mean comparisons were made using a regression approach with years as predictors and confidence bounds estimated using 10,000 random draws from the multivariate normal sampling distribution with mean equal to the maximum-likelihood point estimates, and variance equal to the variance-covariance matrix.<sup>22</sup>



**Figure 1.** National trends for electronic nicotine delivery systems Google searches, 2004-2014.

Note: Both panels display the national trend for all electronic nicotine delivery systems (ENDS) searches as derived from searches originating in the U.S. that included the keywords as described in the text (e.g., *buy e-cigarettes*). Panel (a) compared ENDS searches to searches for snus, Chantix, and nicotine replacement therapies. Panel (b) compared among ENDS searches that included terms indicative of vaping (e.g., *best vaping cigarettes*) or e-cigarettes (e.g., *best e-cigarettes*). Both panels present relative search volumes (100=highest search proportion, 50=50% of the highest search proportion for all Google searches on ENDS). Forecasted values through 2015 are described in the text but not shown here.

Geographic variability in searches was explored to describe the spread of ENDS across the U.S. This relied on comparing ENDS search volume across the lower 48 states by year, formally done by using the maximum likelihood function to estimate the change in SD over time  $likelihood = \sum_x \log(N(0, a + (b-a)*x))$ , where  $a$  and  $b$  are the intercept and slope of the SD and  $N$  is the normal density). This described the year-by-year variability in state-specific search volume. In addition, linear and quadratic models predicting ENDS search volumes using states' longitudes were fitted, based on visual inspection of the data. Analyses were replicated across all ENDS searches and ENDS searches were disaggregated by either e-cigarette or vaping terms.

Variations in searches by tobacco control policies and social norms against smoking ("anti-smoking norms") were explored by comparing ENDS searches across the lower 48 states according to three state-level traits: clean indoor air grades from the American Lung Association updated to 2014,<sup>23</sup> cigarette excise tax rates updated to 2014,<sup>24</sup> and the anti-smoking norms as measured by survey responses.<sup>25</sup> In addition, ENDS searches were compared across the cigarette smoking prevalence in U.S. states as derived from the 2013 Behavioral Risk Factor Surveillance System. Models were executed by fitting bivariable analyses with each of the above as a predictor variable, using a linear function for cigarette excise tax rates, anti-smoking norms, and cigarette smoking prevalence, and categorical dummy indicators for clean indoor air grades given their expression on an "A" to "F" scale. Because these analyses potentially represent multiple testing of the same general (albeit separate, and routinely treated as separate) construct, the alpha was adjusted to correspond to the four tests ( $\alpha = 0.05 \div 4 = 0.0125$ ), even though this did not change the conclusions.

Finally, ENDS searches related to "shopping," seeking information about the "health" aspects of ENDS, or seeking information about the "cessation" aspects of ENDS were quantified building on methods Ayers and Althouse have demonstrated elsewhere.<sup>16,26</sup> First, potential search terms that occurred within ENDS searches indicative of the searcher's motivation or interest were identified based on the authors' familiarity with ENDS searches and in consultations with ENDS experts in their respective centers. Ultimately, terms with strong face validity were selected. For example, the occurrence of the term *buy* in an ENDS query is likely indicative of shopping. For shopping-related searches, ENDS searches that included the terms *buy*, *sale/s*, *shop/s*, or *store/s* were clustered. Similarly, to aggregate health-related searches, ENDS searches that included the terms *health*, *healthy*, *risk*, *risky*, *bad*, *harmful*, *cancer*, or *lung* were clustered; for cessation-related searches, those that included *stop* or *quit* were clustered. For example, *health effects of vaping*, *are e-cigs healthy?*, or *are electronic cigarettes harmful?* would be categorized as health-related (as well as hundreds more searches with these root terms). Second, shopping, health, and cessation ENDS searches were monitored as a percentage of all ENDS searches each week. The resulting trends were then analyzed using methods similar to those for analyzing other trends as detailed above.

## Results

Searches regarding ENDS continue to increase in the U.S., with an estimated 8,498,000 ENDS searches during 2014 alone. All ENDS searches during 2014 (January 1,

2014, through January 1, 2015) were 450% (95% CI=313%, 711%) higher than Ayers and colleagues last reported for 2010, with approximately 1,545,000 ENDS searches in 2010. ENDS continue to be more searched than other smoking alternatives or nicotine-replacement therapies (Figure 1). For example, ENDS searches during 2014 were 6,606% (95% CI=3,700%, 9,800%) or 66 times; 3,899% (95% CI=2,767%, 4,850%); and 3,177% (95% CI=2,433%, 4,350%) greater than searches for snus, nicotine-replacement therapies, and Chantix, respectively.

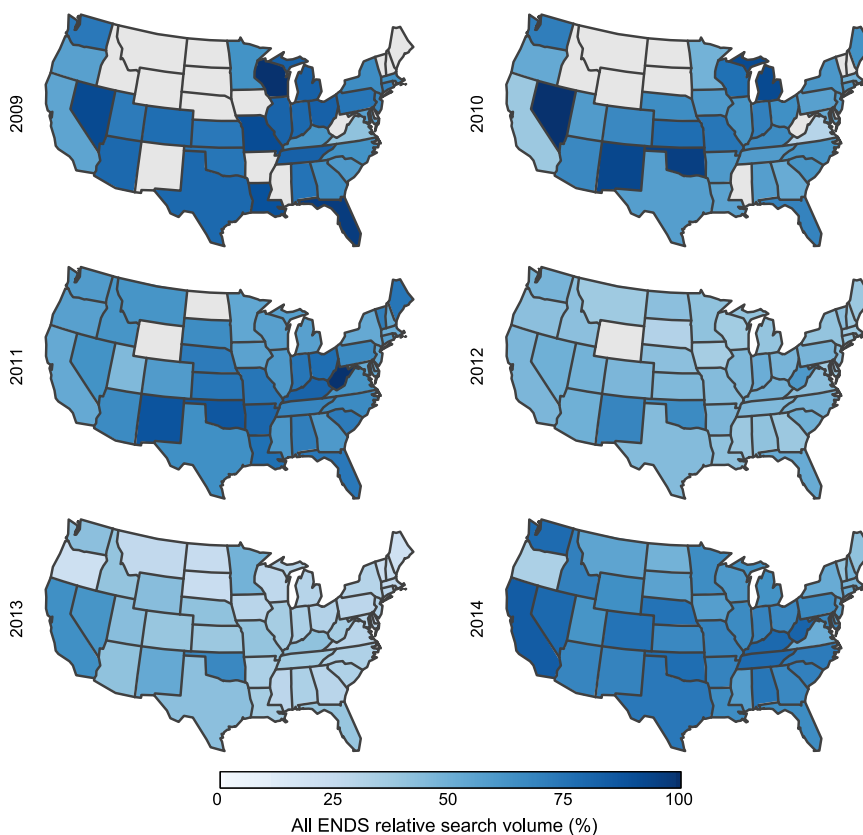
Within the increase in ENDS searches, there was a divergence in the search terms used beginning in 2014. Searches with vaping terms (e.g., *best vapes*) were increasing alongside declines in searches that used more-traditional e-cigarette terms (e.g., *best e-cigarette*). Vaping searches first surpassed e-cigarette searches in May 2014, and by December 2014, vaping searches were 95% (95% CI=76%, 109%) more common than e-cigarette searches.

Statistical forecasts suggest that there will be 62% (95% CI=22%, 95%) more ENDS searches on Google in 2015 than in 2014. Searches with vaping terms are also expected to continue increasing alongside decreasing searches for e-cigarettes, such that by December 2015 vaping searches will likely be 76% (95% CI=68%, 90%) greater than e-cigarette searches.

Between 2009 and 2014, ENDS searches have gone from being concentrated in states like Florida, Nevada, and Texas with fewer searches in the Midwest to being more uniformly searched across the U.S. (Figure 2). The variation between states significantly ( $p < 0.001$ ) declined from 2009 through 2014 (the mean decline in SD across states was 9 [95% CI=2, 76] RSV per year). For instance, during 2009, ENDS searches in Wisconsin were 104% (95% CI=0%, 138%) higher than the mean for the other 50 states, but by 2014, the difference was -7% (95% CI=-46%, 29%) and statistically insignificant.

Yet, two geographic variations remained by 2014. First, searches for ENDS were significantly ( $p < 0.001$ ) more common in Western and Midwestern states than on the Eastern seaboard (Figure 3). Second, the shift toward vaping terms over e-cigarette terms was more common in coastal states ( $p < 0.001$ ), with the exception of a few New England states. For example, for all of 2014, California had the second highest volume of ENDS searches, of which 72% (95% CI=63%, 81%) included vaping terms.

Searches regarding ENDS appeared more common in states with more cigarette smokers (Figure 4), but states with more cigarette smokers were less likely to include vaping terms in their searches, although neither trend was statistically significant ( $p = 0.062$  and  $p = 0.145$ ,



**Figure 2.** The spread of electronic nicotine delivery systems Google searches by U.S. states, 2009–2014.

Note: Each map shows the mean annual relative search volume for all electronic nicotine delivery systems (ENDS) searches. All panels present relative search volumes (100=highest search proportion, 50=50% of the highest search proportion for all Google searches on ENDS). Years prior to 2009 were not presented because searches were near or at zero volume.

respectively). Overall, during 2014, ENDS were searched at similar rates regardless of anti-smoking norms across states ( $p=0.332$ ) or strength of clean indoor air law provisions ( $p=0.260$ ). Yet, more ENDS searches involved vaping terms in states where anti-smoking norms were stronger ( $p<0.004$ ). For example, an increase from the 25th to the 75th percentile for anti-smoking norms predicted a 7% (95% CI=6%, 8%) increase in the proportion of ENDS searches involving vaping terms. ENDS searches were also greater in states with lower cigarette taxes ( $p<0.001$ ), but this pattern did not favor e-cigarette or vaping terms ( $p=0.528$ ). Further inspection of these data suggests the disparity was largely driven by the highest tax states (e.g., New York or Massachusetts).

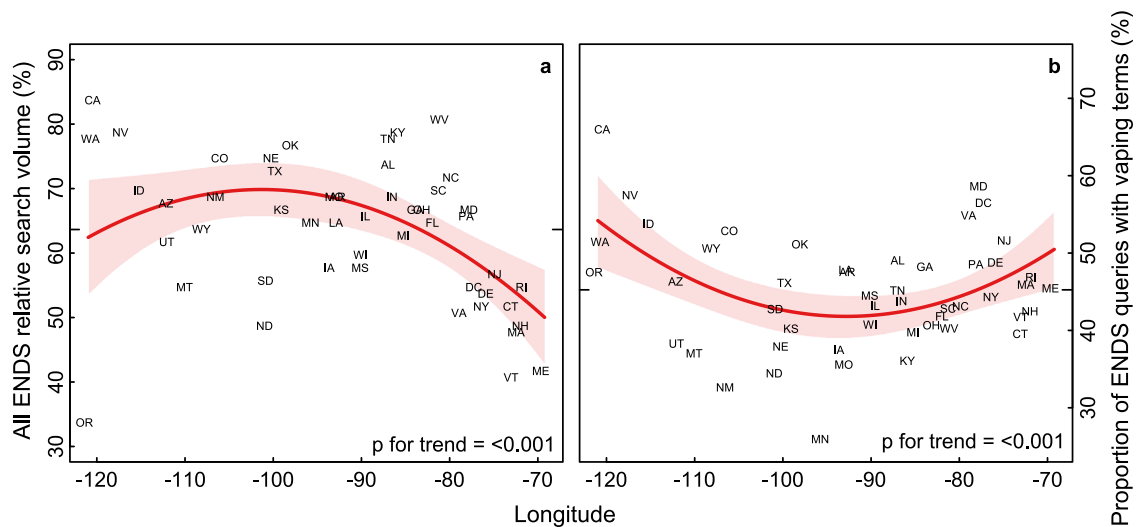
About 6% (95% CI=2%, 10%) and 11% (95% CI=9%, 14%) of all ENDS searches nationally included the terms *store/s*, *shop/s*, *sale/s*, or *buy* during 2013 and 2014, respectively (Appendix Figure 1, available online). As these statistics suggest, the rate at which ENDS searches included shopping terms was growing over time ( $p<0.0001$  for trend). In practical terms, this suggests

there were 333,000 and 934,000 shopping searches in 2013 and 2014, respectively.

By contrast, only 3% (95% CI=1%, 6%) and 2% (95% CI=1%, 4%) of all ENDS searches in 2013 and 2014, respectively, included terms indicative of a health concern (e.g., *vaping healthy* or *e-cigarette risks*). The change in ENDS searches with health terms appeared to decrease over this time period (slope, 0.8 [95% CI=0.3, 1.0] RSV per year;  $p<0.001$ ). Even fewer ENDS searches included cessation terms, such as *do e-cigarettes help smokers quit?*, representing 0.3% (95% CI=0.1%, 0.4%) in 2013 and 0.2% (95% CI=0.001%, 0.5%) in 2014 of all ENDS searches. This change in ENDS searches with cessation terms had a significantly negative slope (−0.09 [95% CI=−0.13, −0.06] RSV per year,  $p<0.001$ ).

## Discussion

Thousands are searching Google for ENDS each day. ENDS searches have increased in every U.S. state, with search terms now shifting from e-cigarettes to vaping, especially in coastal states and states where anti-smoking



**Figure 3.** Longitude predicts electronic nicotine delivery systems (ENDS) Google searches, 2014.

Note: Panel (a) compared all ENDS searches by state to the median state longitude. Searches were measured using the mean relative search volumes (100=highest search proportion, 50=50% of the highest search proportion for all Google searches on ENDS) for all of 2014. Panel (b) compared the proportion of all ENDS searches that included terms indicative of vaping (e.g., *best vaping cigarettes*) by state to the median state longitude.

norms are stronger. When accounting for possible search motivations, it appeared that searches indicative of shopping for ENDS were increasing, whereas searches including health or cessation topics for ENDS both accounted for a smaller proportion of searches overall and have declined over time.

These findings directly address the ENDS surveillance gaps noted in numerous policy statements and review pieces.<sup>27</sup> This study is among the first to describe the vocabulary used by the U.S. population to search for ENDS, to provide statewide estimates of ENDS interest, to estimate the volume of online shopping for ENDS, and to describe how the public seeks out information on ENDS in relation to health and cessation. As such, query-based intelligence has actionable implications for the development of new research questions and further policy debate.

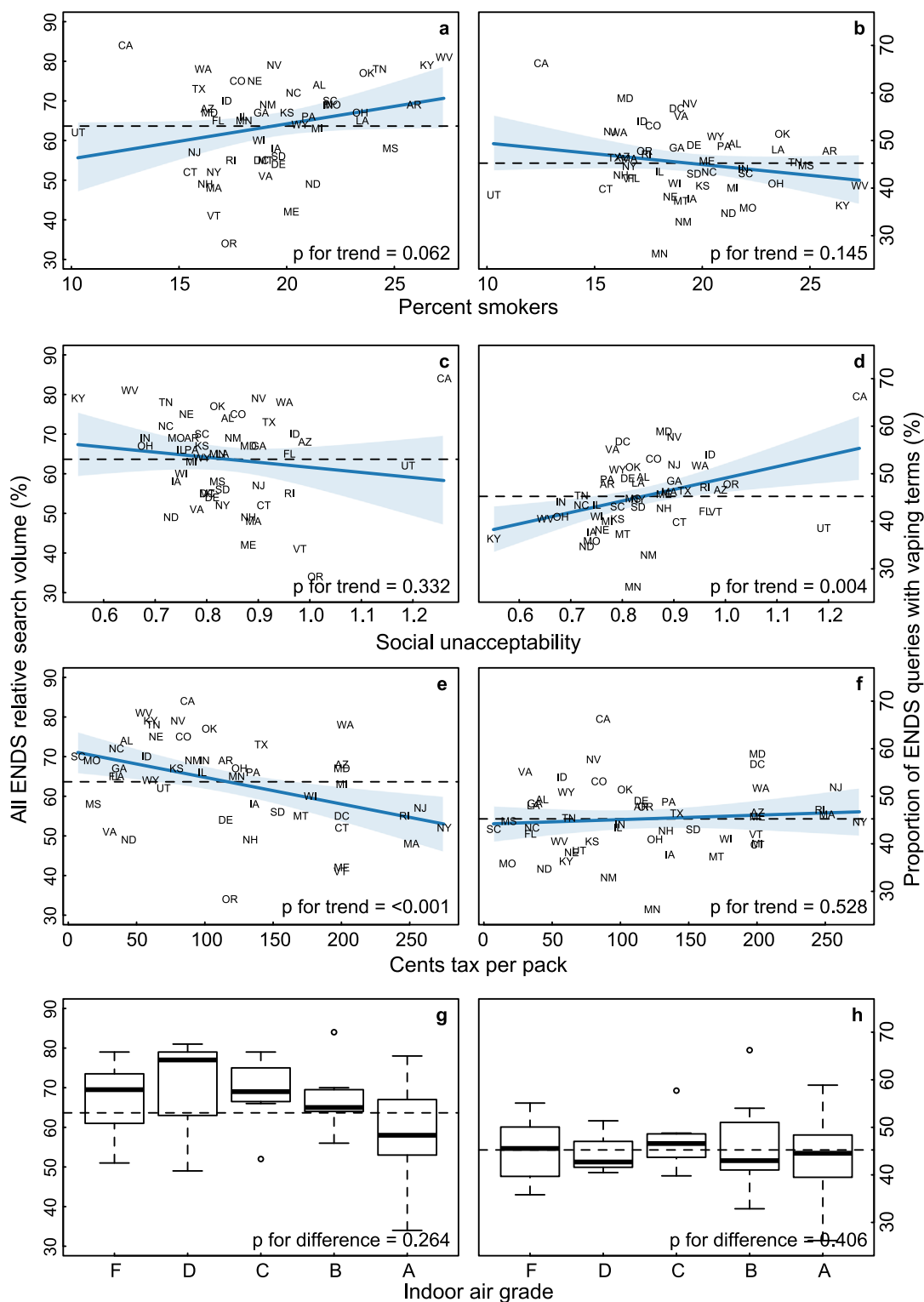
Even though ENDS emerged in the U.S. marketplace fewer than 10 years ago,<sup>28</sup> by 2014, these products were frequently searched in every U.S. state. Searches for ENDS appear to be falling into two broad categories: “vaping” versus ENDS products names, like e-cigarettes. “Vaping” has emerged as the equivalent of “smoking” when referring to ENDS, and the rise in vaping searches is expected to outpace all other ENDS terms. This suggests that surveys might rely on questions that use terms like *vaping* over less commonly used product terms. Moreover, future research might explore the cultural significance of this shift in terminology.

The largely null association between ENDS searches and existing tobacco control measures highlights how

ENDS may be resilient to current tobacco control regulations. For example, ENDS were searched for even more in states with high versus low cigarette taxes<sup>29</sup> and similarly searched for in states with strong versus weak clean indoor air laws.<sup>30</sup> By contrast, there was a strong positive association between anti-smoking norms and vaping searches. This may suggest that ENDS are less stigmatized than combustible products and potentially are being turned to as a means of avoiding stigmatization while maintaining the sensations of cigarette smoking.<sup>31</sup>

Already, millions of Google searches have been made with the likely intention of buying ENDS. Moreover, shopping searches nearly doubled from 2013 to 2014 and are projected to increase. Unlike most other tobacco products, there are no existing federal regulations governing the online sale of ENDS.<sup>32</sup> For instance, one recent study<sup>33</sup> found that 77% of children aged 14–17 years were able to successfully order ENDS online and have them delivered to their home.

Individuals in the U.S. often endorse ENDS as smoking-cessation aids, and some surveys<sup>34–37</sup> suggest that many believe using ENDS will help them quit combustible cigarettes. However, only a small and declining percentage of Google searches for ENDS included terms indicative of cessation. The context of this discrepancy is critical. When primed by survey questions, individuals appear to link ENDS with cessation, but in the privacy of their own home (when no investigator is providing options), it appears that searches for ENDS and cessation are infrequent. This low level of Google searches for cessation is in line with existing



**Figure 4.** Electronic nicotine delivery systems (ENDS) Google searches by select predictors for tobacco control and smoking social norms, 2014.

Note: Panels (a, c, e, and g) compared all ENDS searches in 2014 by state according to the smoking prevalence; social unacceptability of smoking<sup>25</sup>; cigarette excise tax; and clean indoor air grade—as detailed in the text. Searches were measured using the mean relative search volumes (100=highest search proportion, 50=50% of the highest search proportion for all Google searches on ENDS) for all of 2014. Panels (b, d, f, and h) replicate the same analyses but using the proportion of all ENDS searches that included terms indicative of vaping (e.g., *best vaping cigarettes*) by state as the outcome.

evidence on the effectiveness of ENDS for cessation. For instance, a meta-analysis of population-based studies on the association between ENDS and cessation indicated that ENDS are associated with significantly lower odds of quitting combustible cigarettes.<sup>11</sup> These findings are further supported by evidence that adult smokers often use ENDS in combination with other combustible tobacco products<sup>38</sup> and that many adolescents are using ENDS without ever previously smoking cigarettes.<sup>39,40</sup>

It appeared that searches related to the potential health effects of ENDS are becoming more infrequent, whereas the evidence base documenting the health risks of ENDS is only beginning to develop.<sup>41-43</sup> Additional health campaigns are needed to disseminate the scientific knowledge on ENDS use. For example, recent mass media campaigns, including Tips from Former Smokers and the California Department of Public Health's Still Blowing Smoke campaign have piloted advertisements with messages that highlight the known harms of ENDS use and the fact that many ENDS products are produced by the tobacco industry, which has previously engaged in dishonest behavior (stillblowingsmoke.org). Campaigns focused on highlighting risks and encouraging potential ENDS users to understand the risks (or larger state of uncertainty) are feasible given existing infrastructure for anti-tobacco mass media campaigns. Additionally, with increasing online interest in ENDS and shifting trends toward online media consumption, it may be worthwhile to further develop infrastructure to engage in online health communication in addition to other traditional methods that have predominantly focused on TV-based media campaigns.

### Limitations

There are several study limitations to address. First, there is a unique validation challenge with search query surveillance. Typically the validity of new measures are established by comparison with existing gold standards.<sup>44</sup> For instance, the authors have used weekly CDC influenza-like illness trends to validate Google searches for influenza,<sup>18</sup> among a handful of other search validation studies.<sup>45,46</sup> However, in most cases, as with this study, no gold-standard criterion exists. Even so, searches have strong face validity, and confidence in their accuracy is bolstered by the facts that Internet users are demographically similar to ENDS users,<sup>47</sup> many survey-based studies replicated the authors' earlier assessment of ENDS searches<sup>3</sup> or tobacco-related searches generally,<sup>48</sup> and aggregate searches for other tobacco products corresponded to state-level prevalences.<sup>49</sup> Second, discriminating motivation across ENDS searches is more challenging. To overcome this challenge, only highly

specific search terms were used. Yet, a journalist might search *best vape store* to learn about retailers without any personal interest in shopping. Such singular scenarios probably have little impact on aggregate trends given there are tens of thousands of ENDS searches each day. Third, because searches are analyzed at the population level, they cannot be linked to searchers' demographics as done with surveys. Still, search query surveillance and big data generally have numerous strengths over traditional surveillance, especially in behavioral medicine where the thoughts and actions of the population can be directly observed in near real time.<sup>12</sup> Last, search query surveillance can be enhanced by evaluating other forms of big data, such as Facebook<sup>50</sup> or Twitter,<sup>51</sup> with the greatest confidence potentially coming from studies that triangulate big data sources.

### Conclusions

Tobacco control has historically lagged behind online tobacco markets, leaving gaps in surveillance.<sup>52-55</sup> Nowhere is this clearer than with the rise of ENDS. ENDS have become popular during a period without strong surveillance and a slowed public health reaction. Innovative methods like search query surveillance can improve the timeliness of tobacco control surveillance, especially around ENDS. As research agendas are being outlined for ENDS in numerous commentaries and opinion pieces,<sup>56-59</sup> further consideration should be given to the potential benefits of big data streams, like Internet searches. In particular, analyses like herein can both provide critical formative feedback for more costly and labor-intensive investigations, such as informing survey question wording or coverage, and provide determinative insights on questions that may not be assessable using traditional techniques.

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Research reported in this publication was supported by 5R01CA169189-02 and T32CA009492 from the National Cancer Institute (NCI) and U.S. Food and Drug Administration Center for Tobacco Products (CTP) The team's understanding of search query surveillance was enhanced by research experiences supported by NCI and CTP in RCA173299A. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH or the Food and Drug Administration. The funders had no role in the initiation, design, conduct, or interpretation of the study nor the preparation, review, or approval of the manuscript.

Dr. Ayers and Dr. Althouse share an equity stake in a consultancy, Directing Medicine LLC, which advises clinician scientists how to implement some of the methods embodied in this work. Their organization previously advised the larger parent project of Dr. Williams on big data analytics prior to

this study, and has advised other projects based in the Lineberger Comprehensive Cancer Center in the past 5 years. Dr. Dredze has been a paid by Directing Medicine LLC for unrelated work. Dr. Ayers and Dr. Althouse have been separately paid by the University of North Carolina for unrelated speaking engagements and travel in the past 5 years. Neither the data nor the methods described in this article are proprietary. No other financial disclosures were reported by the authors of this paper.

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## Appendix

### Supplementary data

Supplementary data associated with this article can be found at <http://dx.doi.org/10.1016/j.amepre.2015.12.008>.