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

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Abstract

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 large 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 increasing across the entire U.S., with 8,498,180 searches during 2014. At the same time, searches shifted from e-cigarette- to vaping-focused terms, especially in coastal states and states with more anti-smoking norms. 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%), surpassing e-cigarette searches. More ENDS searches were related to shopping (e.g., *vape shop*) than health concerns (e.g., *vaping risks*) or cessation (e.g., *quit smoking with e-cigs*), with shopping searches nearly doubling during 2014.

Conclusions—ENDS popularity is rapidly growing and evolving, and monitoring searches has provided these timely insights. These findings may inform survey questionnaire development for follow-up investigation and immediately guide policy debates about how the public perceives ENDS' health risks or cessation benefits.

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Introduction

Electronic nicotine delivery systems (ENDS) are the first tobacco product born in the online age.[1,2] In 2011, Ayers and colleagues found that Google searches for ENDS in the U.S. were greater than searches for smoking alternatives or cessation devices (at a time when snus was garnering more academic and media attention).[3]

These findings have been confirmed and expanded on by telephone surveys that find awareness and use of ENDS is increasing.[4–10] Yet, ENDS surveillance remains limited. Surveys focused on ENDS are often too costly to regularly implement and their results are often not revealed until long after the data are first collected. As a result, public health is unable to stay on top of potential changes in public perceptions. For example, most studies have used sampling frames designed to obtain nationally representative cross-sectional estimates of ENDS use, but little is known about how perceptions and interest around ENDS varies sub-nationally or changes over time.[11]

Continued analysis of Google search trends may fill some of these knowledge gaps and outline agendas for follow-up survey-based surveillance.[12–15] Examining the content of searches can reveal the searcher's thoughts and potential motivation for searching,[16] such as seeking information for purchasing ENDS, whether ENDS aid cessation, or whether using ENDS poses 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). Google Trends is a public index of search activity for specific search terms or categories of terms, 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). Hundreds of studies have used Google Trends for public health insights,[17] including several recent examples from this journal.[18–20] 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 for the composite of all ENDS search terns were described nationally. Trends were then explored by disaggregating among those that included e-cigarette (e.g., *ecig*, *electronic cigs*, and *e-cigarettes*) and 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.[3] 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 in Hyndman and Khandakar.[21] Mean comparisons were made using a regression approach with years as predictors and confidence bounds estimated by 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.[22]

Geographic variability in searches was explored to describe the spread of ENDS. This relied on comparing ENDS search volume across the lower 48 states by year, formally done by using the maximum likelihood to estimate the change in SD over time (*likelihood* = $\Sigma_x \log(N(0, a + (b − a)^* x)$, 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,[23] cigarette excise tax rates updated to 2014,[24] and the anti-smoking norms of cigarette smoking as measured by survey responses.[25] In addition, ENDS searches were compared across the cigarette smoking prevalences of 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 variables, 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 a "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 (α=0.05 ÷ 4 = 0.0125), even though this did not change the conclusions of the results.

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 the authors have demonstrated elsewhere.[16,26] 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, the authors monitored

shopping, health, and cessation ENDS searches 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, with an estimated 8,498,180 ENDS searches during 2014. All ENDS searches during 2014 (January 1, 2014 through January 1, 2015) were 450% (95% CI=313%, 711%) higher than the authors last reported for 2010, with approximately 1,545,123 ENDS searches in 2010. ENDS continue to be more searched than other smoking alternatives or nicotine-replacement therapies. 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.

The present 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 $p=0.145$, 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), after adjusting for multiple tests (α=0.05 ÷ 4 = 0.0125). 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 (Figure 5). 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 333,092 and 934,800 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] 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 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 accounted for both 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.[27] This study is among the first to describe the vocabulary used by the 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' health and cessation implications. 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,[28] 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[29] and similarly searched for in states with strong versus weak clean indoor air laws.[30] By contrast, there was a strong positive association between anti-smoking norms and vaping searches. This suggests 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.[31]

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.[32] For instance, one recent study found that 77% of children aged 14–17 years were able to successfully order ENDS online and have them delivered to their home.[33]

Individuals in the U.S. often endorse ENDS as smoking cessation aids and some surveys suggest that many believe using ENDS will help them quit combustible cigarettes.[34–37] 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 evidence on the effectiveness of ENDS for cessation. For instance, a meta-analysis of population-based studies of the association between ENDS and cessation indicated that ENDS are associated with significantly lower odds of quitting combustible cigarettes.[11] These findings are further supported by evidence that adult smokers often use ENDS in combination with other combustible tobacco products[38] and that many adolescents are using ENDS without ever previously smoking cigarettes.[39,40]

It appeared that searches related to the potential health effects of ENDS are becoming more infrequent, whereas the evidence base for the health risks about ENDS is beginning to accumulate.[41–43] 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 who 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.[44] For instance, the authors have used weekly CDC influenza-like illness trends to validate Google searches for influenza,[18] among a handful of other search validation studies.[45,46] However, in most cases, as with this study, no survey-based 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,[47] many survey-based studies replicated the authors' earlier assessment of ENDS searches,[3] and aggregate searches for other tobacco products corresponded to state-level prevalences.[48] 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 thousands of ENDS searches each day. Third, because searches are analyzed at the population level, they cannot be linked to searchers' demographics like 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 passively observed in near real time.[12]

Conclusions

Tobacco control has historically lagged behind online tobacco markets, leaving gaps in surveillance.[49–52] 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,[53–56] 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.

Acknowledgments

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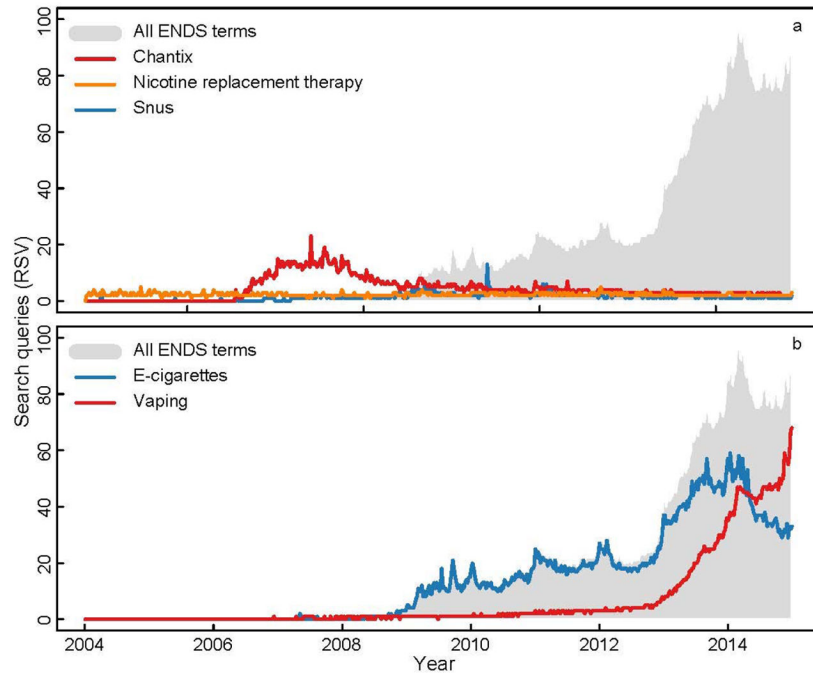
Figure 1. National trends for electronic nicotine delivery systems Google searches, 2004–2014
Both panels display the national trend for all electronic nicotine delivery systems (ENDS) searches as derived from searches originating in the U.S. that included the keywords as described in the text (e.g., "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.
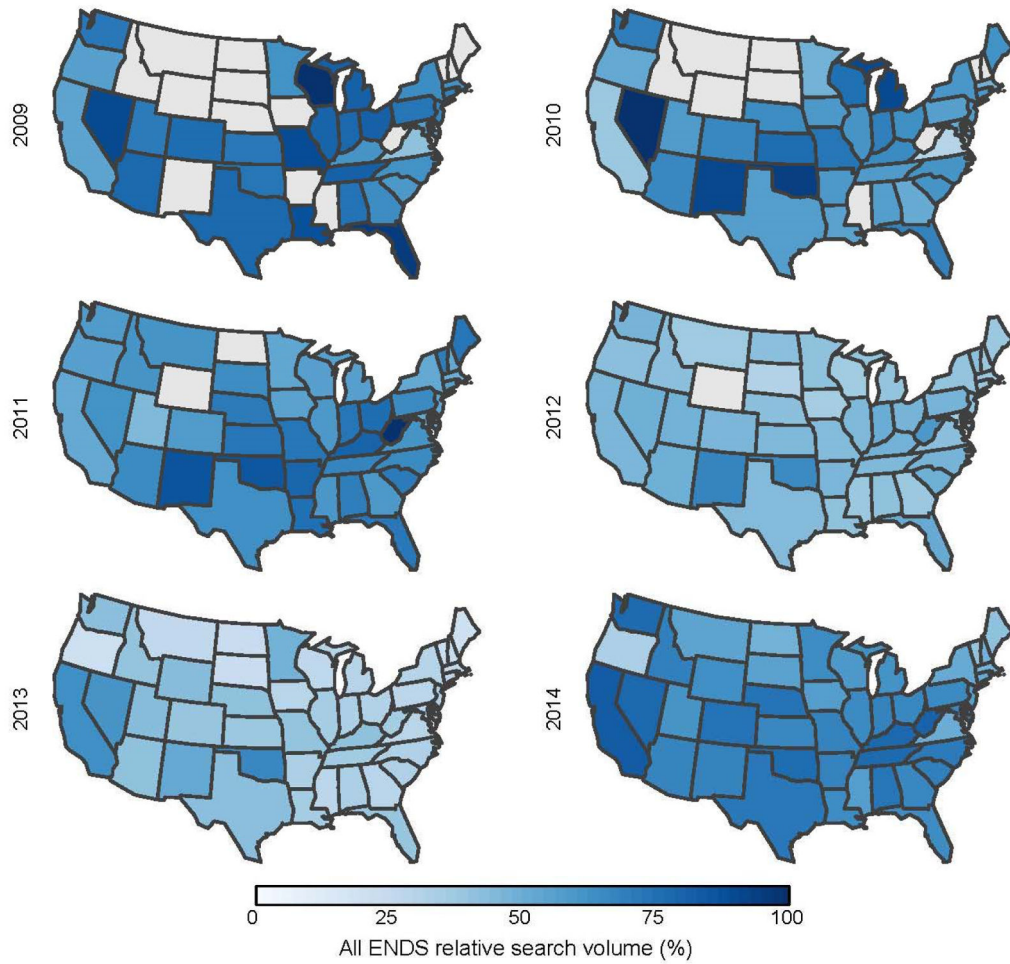
Figure 2. The spread of electronic nicotine delivery systems Google searches by U.S. states, 2009–2014

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.
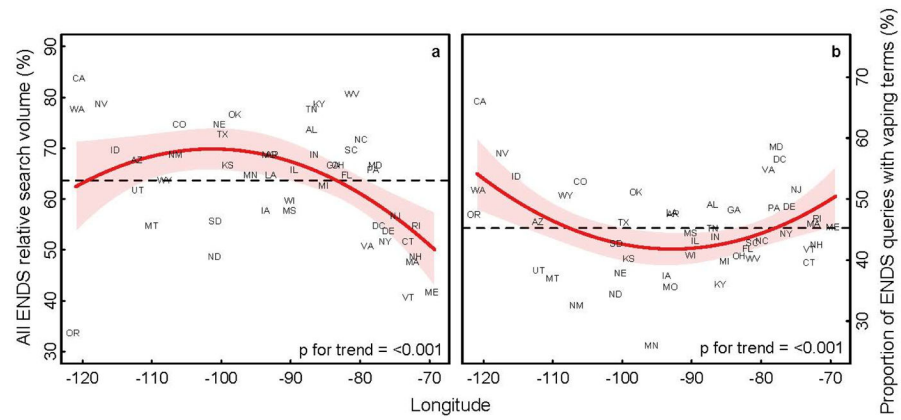
Figure 3. Longitude predicts electronic nicotine delivery systems Google searches, 2014
Panel (a) compared all ENDS searches by state to the median state longitude. Searches were measured using the mean relative search volumes (100=highest search proportion, 50=50% of the highest search proportion for 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.
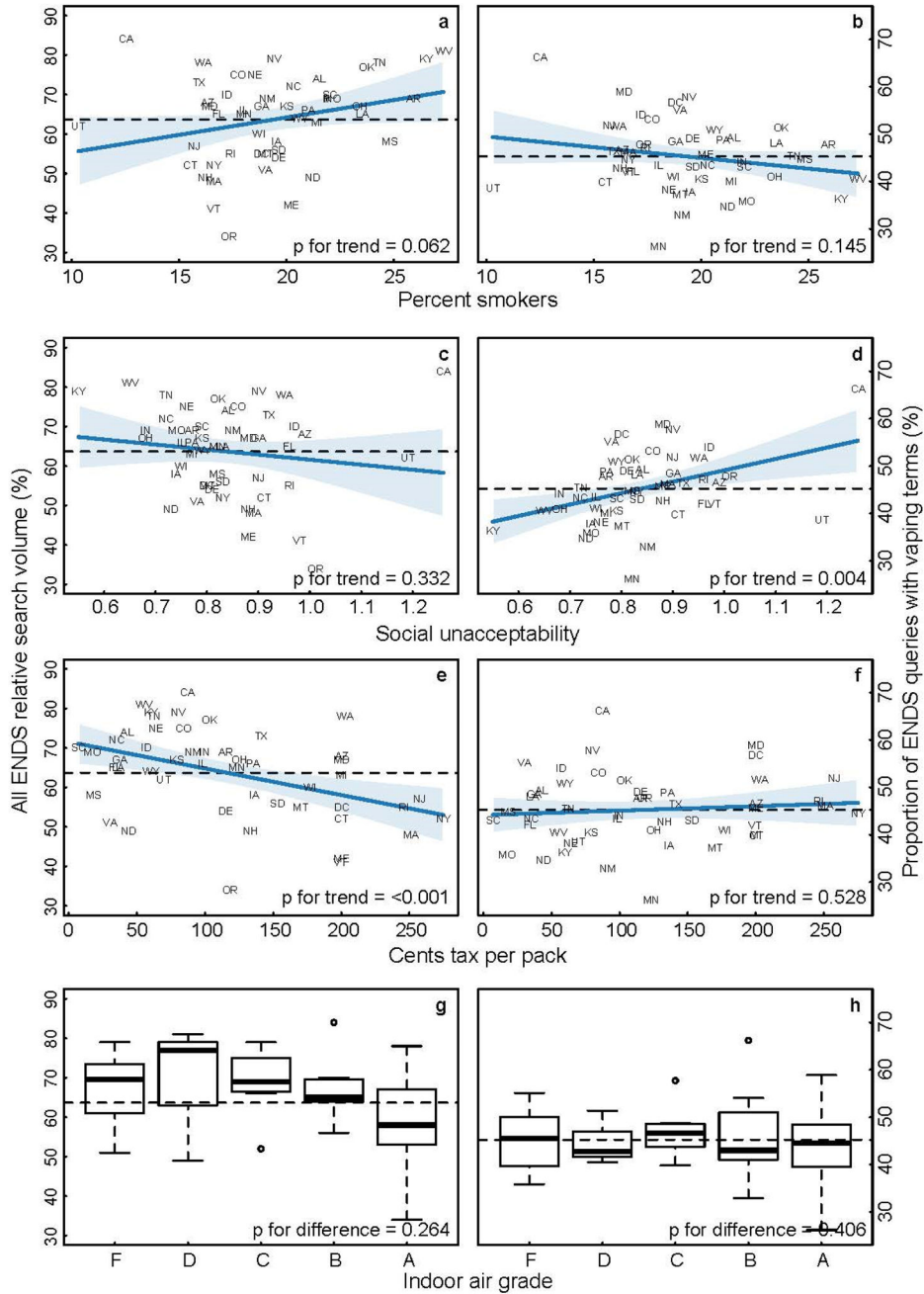
Figure 4. Electronic nicotine delivery systems Google searches by select predictors for tobacco control and smoking social norms, 2014

Panels (a, c, e, and g) compared all ENDS searches in 2014 by state according to the smoking prevalence, social unacceptability of smoking,(20) 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.
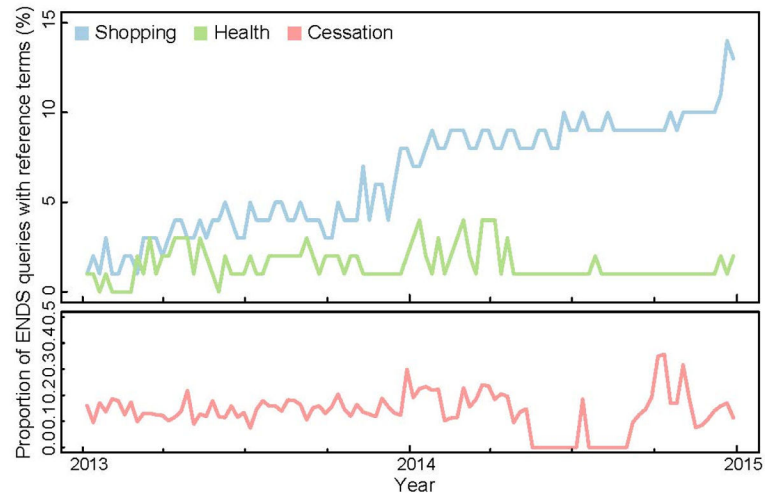
Figure 5. Electronic nicotine delivery systems Google searches including shopping, health, or cessation, 2014

Each line shows the proportion of all ENDS searches that also included terms consistent with shopping (e.g., "buy"), health (e.g., "harmful"), or cessation (e.g., "quit"), as detailed in the text. Cessation is shown on a separate scale, given searches were rare in this category.