

Tracking the Rise in Popularity of Electronic Nicotine Delivery Systems (Electronic Cigarettes) Using Search Query Surveillance

John W. Ayers, MA, Kurt M. Ribisl, PhD, John S. Brownstein, PhD

This activity is available for CME credit. See page A3 for information.

Background: Public interest in electronic nicotine delivery systems (ENDS) is undocumented.

Purpose: By monitoring search queries, ENDS popularity and correlates of their popularity were assessed in Australia, Canada, the United Kingdom (UK), and the U.S.

Methods: English-language Google searches conducted from January 2008 through September 2010 were compared to snus, nicotine replacement therapy (NRT), and Chantix® or Champix®. Searches for each week were scaled to the highest weekly search proportion (100), with lower values indicating the relative search proportion compared to the highest-proportion week (e.g., 50=50% of the highest observed proportion). Analyses were performed in 2010.

Results: From July 2008 through February 2010, ENDS searches increased in all nations studied except Australia, where an increase occurred more recently. By September 2010, ENDS searches were several-hundred-fold greater than searches for smoking alternatives in the UK and U.S., and were rivaling alternatives in Australia and Canada. Across nations, ENDS searches were highest in the U.S., followed by similar search intensity in Canada and the UK, with Australia having the fewest ENDS searches. Stronger tobacco control, created by clean indoor air laws, cigarette taxes, and anti-smoking populations, were associated with consistently higher levels of ENDS searches.

Conclusions: The online popularity of ENDS has surpassed that of snus and NRTs, which have been on the market for far longer, and is quickly outpacing Chantix or Champix. In part, the association between ENDS's popularity and stronger tobacco control suggests ENDS are used to bypass, or quit in response to, smoking restrictions. Search query surveillance is a valuable, real-time, free, and public method to evaluate the diffusion of new health products. This method may be generalized to other behavioral, biological, informational, or psychological outcomes manifested on search engines.

(Am J Prev Med 2011;40(4):448–453) © 2011 American Journal of Preventive Medicine

Introduction

Electronic nicotine delivery systems (ENDS), or “electronic cigarettes,” consist of a plastic tube, electronic heating element, and liquid nicotine cartridge.¹ When activated, the heating element vapor-

izes the liquid nicotine, and the steam is absorbed orally. ENDS do not always resemble cigarettes, and flavors range from bubblegum to tobacco.^{2,3} The nicotine delivery and health effects of ENDS are conflicting, but they have been under-studied.^{4–6} Nicotine cravings were lower 1 hour after using a 16-mg nicotine-dosing ENDS in a placebo-control trial,⁷ whereas laboratory assessment suggested nicotine delivery was limited⁸ and differed by puffing style.⁹ Although ENDS do not burn tobacco, some cartridges include cigarette toxins, and “nicotine free” cartridges sometimes contain nicotine.¹⁰

ENDS are an adaptation to the health, legal, and social consequences of smoking. ENDS are promoted as a safer, fashionable, and tech-savvy alternative that can be “smoked anywhere”—so smokers need not curtail their habit (www.smokeanywhere.com). However, ENDS are

From the Johns Hopkins Bloomberg School of Public Health (Ayers), Baltimore, Maryland; the Center for Behavioral Epidemiology and Community Health (Ayers), San Diego, California; the Gillings School of Global Public Health (Ribisl), the Lineberger Comprehensive Cancer Center (Ribisl), University of North Carolina, Chapel Hill, North Carolina; the Department of Pediatrics, Harvard Medical School (Brownstein); and the Children's Hospital Informatics Program, Harvard-MIT Division of Health Sciences and Technology (Brownstein), Boston, Massachusetts

Address correspondence to: John W. Ayers, MA, Johns Hopkins Bloomberg School of Public Health, 624 N. Broadway, Room 263, Baltimore MD 21205. E-mail: jayers@jhsph.edu.

0749-3797/\$17.00

doi: 10.1016/j.amepre.2010.12.007

also marketed for cessation. In an August 2009 Zogby poll (N=4611), almost half of U.S. adults believed ENDS should be an available cessation option.¹¹ A study group of smokers preferred ENDS to an inhaler for cessation.⁷

Among smoking alternatives, ENDS have likely received the greatest advocacy, policy, and media attention. However, the popularity of ENDS remains unstudied. Because ENDS are promoted online,⁴ search queries are a useful signal of their popularity.^{12–18} It was hypothesized ENDS searches would be greater in the context of stronger tobacco control, because ENDS may be used for cessation in the face of, or circumvention of, tobacco control.

Methods

Data were obtained from *Google Insights for Search* (www.google.com/insights/search/), a real-time, free, and public monitoring of Google search queries. Search queries indicative of ENDS were analyzed in comparison to four other smoking alternatives: snus; a pasteurized tobacco mint taken orally and marketed for use in smokefree places¹⁹; NRTs²⁰; and varenicline, an alpha-4 beta-2 nicotinic acetylcholine receptor partial agonist, trade-named Chantix® or Champix®.²¹ The assessment covered the time period from ENDS's debut to September 2010, and included four English-speaking countries: Australia, Canada, the United Kingdom (UK), and the U.S. *Insights* produces relative search volume (RSV) indicators scaled to the highest search proportion week (RSV=100). RSV values less than 100 demonstrate how other weekly search proportions compared to the highest search proportion (e.g., 50 RSV=50% of the highest observed search proportion).

Initially, a root term was identified for each smoking alternative product (e.g., “electronic cigarettes”), and related terms were added, according to their internal consistency, to form a composite for each product. Details are shown in Appendix A (available online at www.ajpm-online.net). Because varenicline was trade-named Chantix in the U.S. and Champix elsewhere, different search terms were used. Unclear terms (e.g., “the patch” can refer to software patches) were omitted. The terms analyzed were face valid, and alternative root terms resulted in similar composites.

Second, term composites were used to derive a single RSV by product. An appraisal was made of ENDS and their alternatives' RSV for Australia, Canada, the UK, and U.S., with comparison among other smoking alternatives *within* nations (each nation on its own RSV scale) and *across* nations (all nations on the same RSV scale) each week from January 2008 through September 2010. Search histories for snus in Australia were unavailable. For visual comparison, locally weighted scatterplot smoothing (lowess) was used to layer a mean RSV trend over the raw data in the figures.²² For statistical comparison, the time trends were segmented and compared using an equality-of-means test. To test the hypothesis that ENDS searches were greater in a context of stronger tobacco control, ENDS RSV means were compared among the 15 largest U.S. states, where two thirds of U.S. residents reside.²³ “A” or “B” clean indoor air grade states from the 2008 American Lung Association were compared with other states.²⁴ States with at least the M + 1 SD cigarette tax in 2009 were compared with other states.²⁵

The five states with the strongest anti-smoking populations were compared to other states.²⁶ All tests were two-tailed, $p < 0.05$.

Results

Electronic nicotine delivery systems searches surged during surveillance, having the highest (100) RSV in the UK and U.S. compared to snus, NRTs, and Chantix or Champix (Figure 1).

ENDS searches in Canada, the UK, and U.S. first eclipsed snus searches in 2008, and remained consistently higher. In Canada and the UK, for example, snus searches were stable around 5% and 10%, respectively, of the highest proportion of ENDS searches (RSV=5, 10). Early in 2009, snus searches steadily increased in the U.S. but dissipated quickly, stabilizing at a level far lower than that for ENDS. During the last week of monitoring, September 19–25, 2010, ENDS searches were greater than snus searches by 550% in the U.S. (82 vs 15 RSV); 520% in Canada (26 vs 5 RSV); and 870% in the UK (62 vs 7 RSV), using a risk ratio (e.g., $[RSV_{ENDS}/RSV_{snus}]$).

In all nations, ENDS searches were higher than NRT searches since late 2008. For example, during the fall of 2008 (October 5–11), ENDS searches first eclipsed NRT searches (15 vs 12 RSV) in the U.S. and recently exceeded NRT searches by many-hundred-fold. In contrast to ENDS search trends, NRT search trends were stable or declined in all nations (e.g., in Canada, RSV was highest during the *first week* of surveillance).

Chantix or Champix searches peaked early during surveillance and steadily decreased thereafter, except in Australia. During late 2008 and early 2009, ENDS searches in the UK and U.S., respectively, surpassed that for Chantix or Champix. During the last week of monitoring, ENDS's RSV was 300% (82 vs 27 RSV) and 160% (61 vs 39 RSV) higher than Chantix or Champix in the U.S. and UK, respectively. In Australia and Canada, ENDS searches have recently rivaled or surpassed Chantix or Champix searches.

Estimating Electronic Nicotine Delivery Systems Popularity Across Nations

Although ENDS emerged in all the markets in early 2008, searches increased more rapidly in the U.S. and UK than in Australia or Canada (Figure 2). For example, ENDS RSV typically increased 0.50 and 0.85 per week in the U.S. and UK during the second half of 2008, whereas trends were stable elsewhere. Australian and Canadian searches never surpassed 40% of the highest ENDS RSV in the U.S., except around New Year's, a time of cessation resolutions. ENDS RSV for the last 8 weeks of surveillance (August and September 2010) was twice as great in the U.S. (64, 95% CI=61, 68) compared to the UK (31, 95% CI=29, 33), Canada (32, 95% CI=27, 37) or Australia (21, 95% CI=16, 26). Cyclic New Year's pulses also emerged

across nations. For example, after New Year's 2010, the RSV of ENDS searches spiked, reaching peak or near-peak levels.

The Role of Tobacco Control Mechanisms Across U.S. States

Search trends by U.S. states' level of tobacco control suggest states with stronger tobacco control had more ENDS searches than states with weaker tobacco control, as hypothesized (Figure 3). For example, states with A or B American Lung Association clean indoor air grades had on average a 5% (95% CI=4, 5, $p<0.001$) higher ENDS RSV than other states during 2009. The patterns were similar across a range of controls, including cigarette taxation or anti-smoking sentiments among residents.

Information-Seeking Versus Shopping

It is unclear whether search queries indicate curiosity or shopping. Therefore, the prior models were replicated by restricting the analysis to shopping searches, defined as those in which users solicit purchase information directly from suppliers with prices and shipping costs clearly displayed (Appendix B, available online at www.ajpm-online.net). About 50%–75% of all ENDS searches in the U.S. and UK were shopping searches, compared to 10%–25% in Australia and 25%–50% in Canada. Shopping search trends grossly followed those for all ENDS searches (except those for Chantix or Champix, which are not legally available online), suggesting ENDS search trends for information-seeking also apply to shopping.

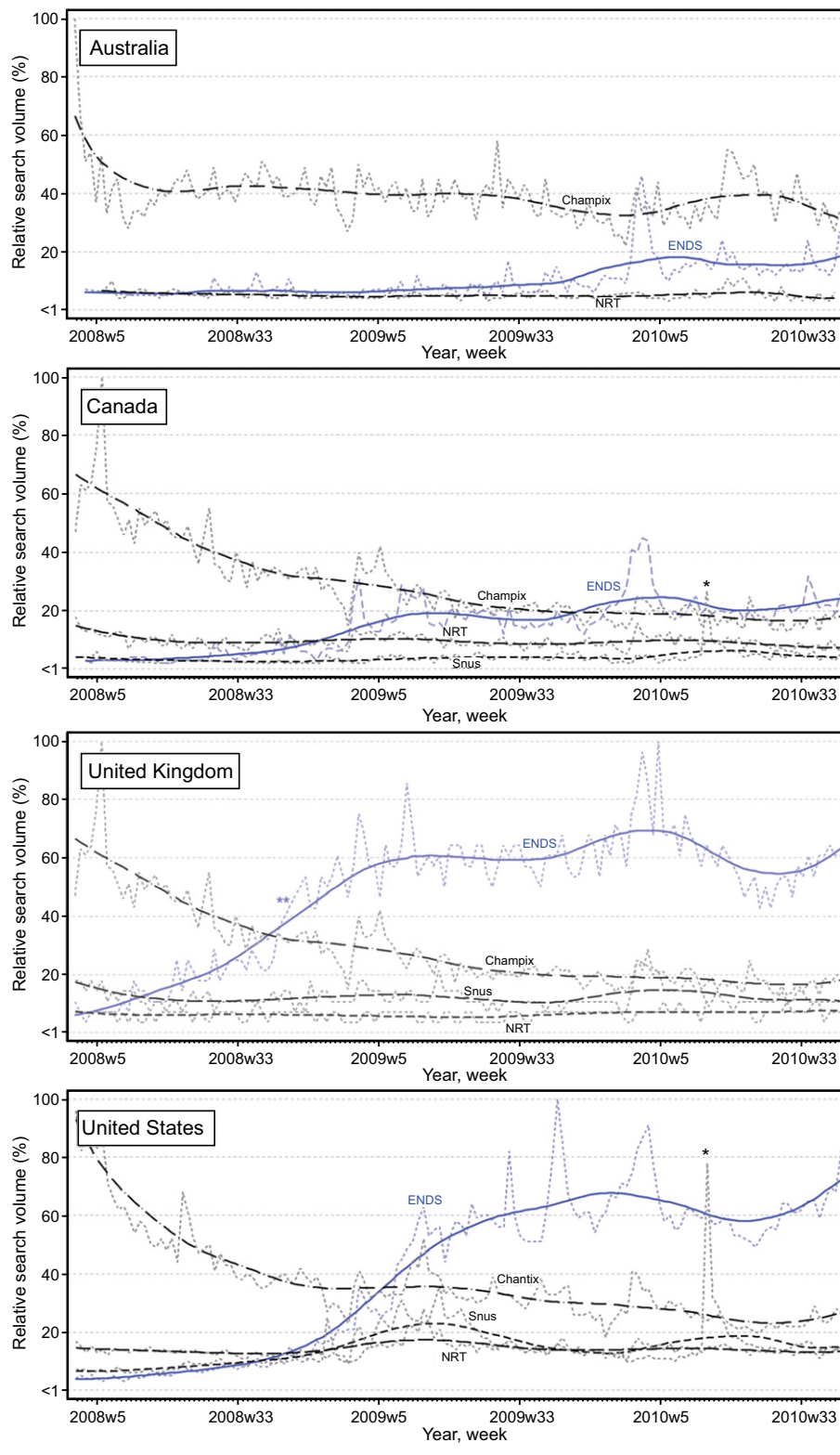


Figure 1. National search trends for ENDS relative to their alternatives. The bold lines indicate the weekly running trend fitted using lowest (bandwidth=0.30); the background trends are the raw relative search volume values. *Corresponds with a 60 Minutes news story on snus; **estimates have been omitted for this period. ENDS, electronic nicotine delivery systems

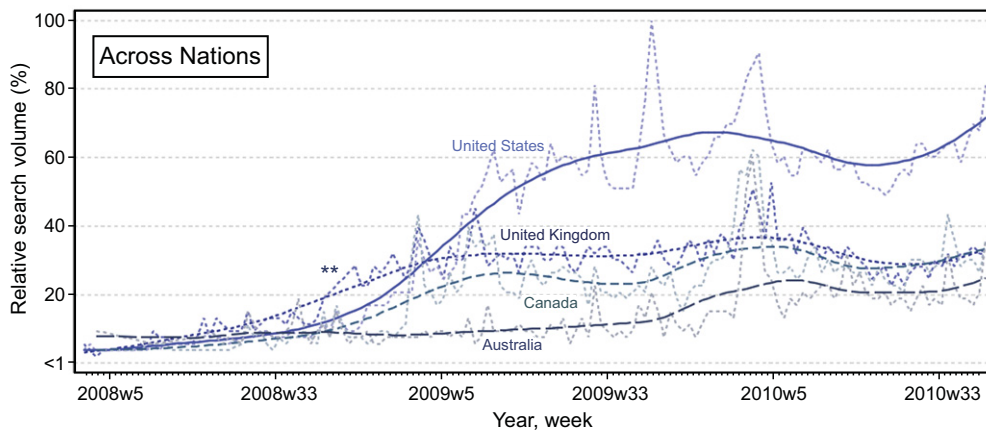


Figure 2. Comparing search trends for electronic nicotine delivery systems across nations. The bold lines indicate the weekly running trend fitted using lowess (bandwidth=0.30); the background trends are the raw values. **Estimates have been omitted for this period.

Discussion

Electronic nicotine delivery systems have emerged as an online leader in popularity among smoking alternatives in Canada, the UK, and U.S. and a strong rival in Australia. Across nations, ENDS online popularity was greatest in the U.S. Online interest peaked with cyclic trends around New Years, which is when cessation pledges are popular. Trans-geographic analysis²⁷ suggested ENDS searches were greater under stronger tobacco control, suggesting ENDS helps smokers circumvent or quit in response to smoking restrictions. Moreover, search trends for shopping and information-seeking ENDS searches were similar, implying that searches may lead to purchases.

Strengths and Limitations

The strengths of this report center on the application of search query surveillance to assess END's popularity, where data were unavailable through traditional means. The Internet is a critical health information resource; thus, monitoring search queries has implications for understanding health. Search query surveillance, however, has limitations, both general and specific to this work, that need to be addressed.

The validity of search query surveillance for health behaviors is uncertain. Search queries, however, can predict outbreaks of influenza-like,^{14–16} gastrointestinal,¹³ and Lyme¹⁸ diseases independent of media coverage. Econometricians have pioneered search query surveillance of behaviors, showing that search queries can predict film revenue, video game sales, music chart performance,²⁸ and unemployment rates.²⁹ It has been suggested²⁸ that search queries reveal relevant details about present behavior and provide a useful guide for forecasting future behavior, especially when no other data are available. These findings suggest that ENDS searches may be framed as indicators of popularity, espe-

cially when these products have limited availability at offline retailers. Moreover, search motivation may be inferred through careful attention to search category (e.g., shopping) and terms (e.g., “e-cig side effects”), although the latter awaits further investigation.

Composite search terms may vary geographically, biasing the current estimates; however, the terms herein appeared to be

grossly transnational and state appropriate. Continued evaluation of searches should be sensitive to how ENDS search terms change, especially given that ENDS remain novel. States with strong clean indoor air laws typically had higher cigarette taxes and larger anti-smoking populations, so the association between any one mechanism and ENDS searches could be a result of another mechanism.

Google does not provide search volume data. It is unclear how many searches for ENDS are occurring because 10 of 50 at t relative to 10,000 of 50,000 at $t + 1$ yield equivalent RSVs. However, relative measures (e.g., ORs) are common in health research and useful to indicate change. As traditional data become available, these can be linked to RSV, so the current estimates shed light on absolute ENDS interest. However, one ENDS webpage, www.smokingeverywhere.com, averaged 250,000 unique monthly visitors in 2009, about nine times more than www.quitsmoke.gov.⁴

Implications

About 4.5% of all search queries are health-related^{30,31}; still, this was an early study to use search query surveillance for health behaviors. Prior studies^{12–14,16,17} largely focused on infectious diseases. However, Internet saturation is greatest in affluent countries where health behaviors such as smoking, not infectious disease, are the leading causes of premature death.³² The current surveillance application, and others,³³ is in accordance with a computational social science that draws on a 21st-century society's digital footprints.^{34,35}

Several governing bodies have restricted ENDS sales. Canada actively banned ENDS sales,³⁶ whereas Australia's preexisting policies preclude ENDS sales for recreational purposes, although purchases and possession may

be allowed.³⁷ The role of ENDS in the U.S. pharmaceutical and recreational market remains unclear, pending additional Food and Drug Administration responses, but some states have independently restricted ENDS sales. For example, Oregon stopped selling ENDS at state outlets.³⁸ However, these policies appeared ineffectual at curtailing online interest. If necessary, policies tailored to online markets may be needed, similar to regulatory strategies designed to combat Internet cigarette vendors.^{39–41}

Ideally, surveying ENDS searchers will help those in the field learn more about motivation for using ENDS. This strategy was recently used,⁴² but the sample was drawn from a smoking-cessation website. As a result, findings that ENDS users were typically seeking cessation were confounded by the sampling strategy. Ensuring that participant selection is independent of the outcomes being investigated⁴³ is critical for online surveys, where users cluster around interests. Search engine sampling may reduce such biases.

Conclusion

It is an open question whether ENDS popularity indicates a hope for harm reduction or a threat to public health. In either case, rapid expansion of both novel

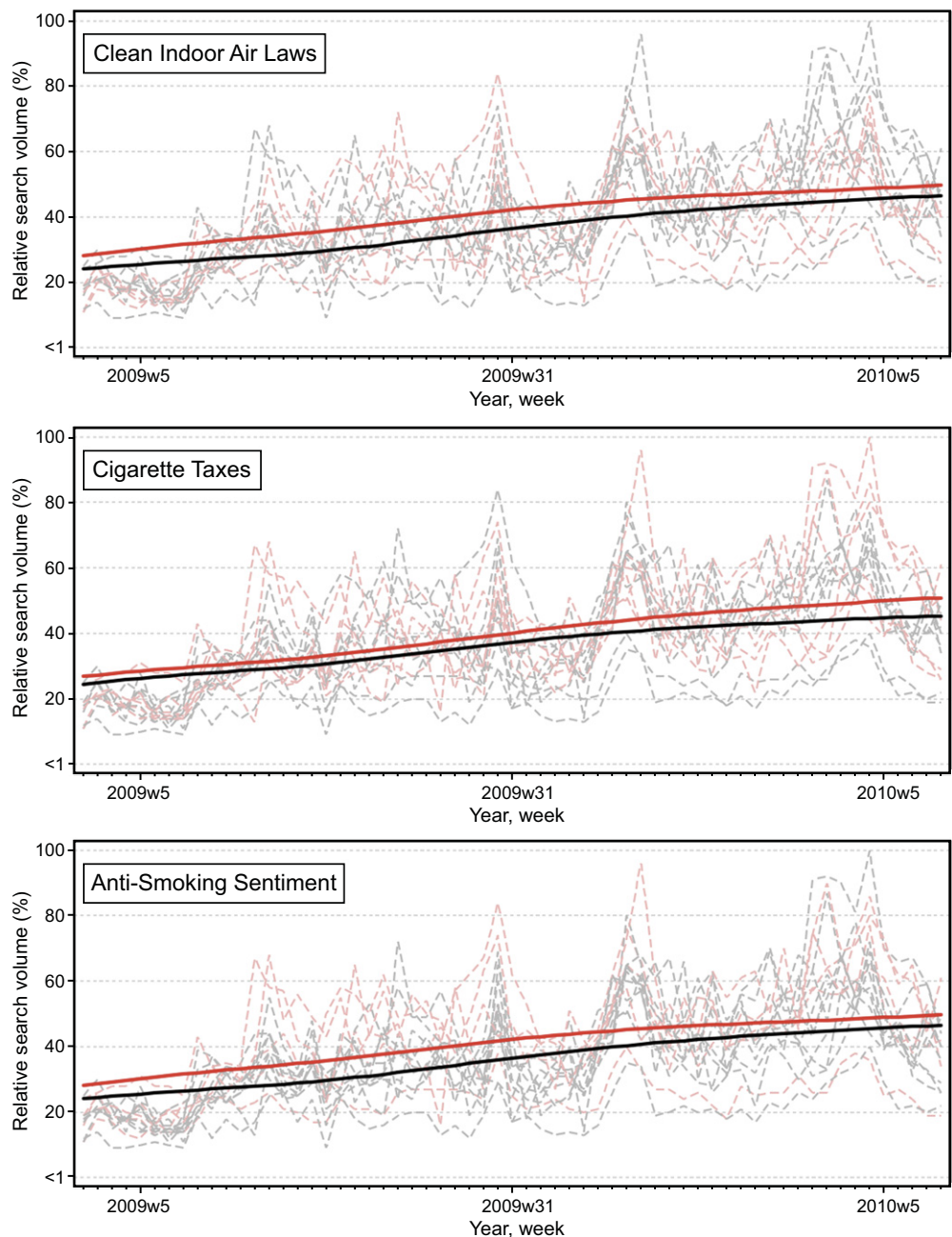


Figure 3. Search trends for ENDS among the 15 largest U.S. states by tobacco control mechanisms during 2009

(a) Highlights states with an A or B clean indoor air law grade from the American Lung Association; (b) highlights states with the $M + 1$ SD or higher cigarette tax; (c) highlights the five states with the strongest anti-smoking attitudes. The bold lines indicate the weekly running mean for strong, versus weak, tobacco control for each mechanism (a–c), fitted using a lowest mean (bandwidth=0.99). The background lines are raw trends.

ENDS, electronic nicotine delivery systems

and traditional methods for assessing ENDS popularity and use is required. Search query surveillance is a valuable real-time, free and public method to evaluate the diffusion of new health products, like ENDS. In principle, search query surveillance is generalizable to

other behavioral, biological, informational, or psychological outcomes manifested online.

This research was supported by research funding from [Google.org](#) and the National Library of Medicine (NIH) to JSB. Earlier versions of this manuscript were improved by discussion with C. Richard Hofstetter, Melbourne Hovell, Carl Latkin, John McGready, and Keith Schnakenberg.

No financial disclosures were reported by the authors of this paper.

References

1. WHO. WHO regulatory consultation on the safety of electronic nicotine delivery devices (ENDS). Geneva, Switzerland: WHO, 2010.
2. Kuehn BM. FDA: electronic cigarettes may be risky. *J Am Med Assoc* 2009;302(9):937.
3. Pauly J, Li Q, Barry MB. Tobacco-free electronic cigarettes and cigars deliver nicotine and generate concern. *Tob Control* 2007;16:357.
4. Yamin CK, Bitton A, Bates DW. E-cigarettes: a rapidly growing Internet phenomenon. *Ann Intern Med* 2010;153:607–9.
5. Henningfield JE, Zaatari GS. Electronic nicotine delivery systems: emerging science foundation for policy. *Tob Control* 2010;19(2):89–90.
6. Wollscheid KA, Kremzner ME. Electronic cigarettes: safety concerns and regulatory issues. *Am J Health Syst Pharm* 2009;66(19):1740–2.
7. Bullen C, McRobbie H, Thornley S, Glover M, Lin R, Laugesen M. Effect of an electronic nicotine delivery device (e cigarette) on desire to smoke and withdrawal, user preferences and nicotine delivery: randomized crossover trial. *Tob Control* 2010;19(2):98–103.
8. Eissenberg T. Electronic nicotine delivery devices: ineffective nicotine delivery and craving suppression after acute administration. *Tob Control* 2010;19(1):87–8.
9. Trtchounian A, Williams M, Talbot P. Conventional and electronic cigarettes (e-cigarettes) have different smoking characteristics. *Nicotine Tob Res* 2010;12(9):905–12.
10. Westenberger BJ. Evaluation of e-cigarettes. USDHHS, Food and Drug Administration, 2009. www.fda.gov/downloads/Drugs/ScienceResearch/UCM173250.pdf.
11. Zogby Poll. Electronic cigarettes find fans, but most want regulation. www.zogby.com/news/readnews.cfm?ID=1748.
12. Brownstein JS, Freifeld CC, Madoff LC. Digital disease detection—harnessing the web for public health surveillance. *N Engl J Med* 2009;360(21):2153–5, 2157.
13. Wilson K, Brownstein JS. Early detection of disease outbreaks using the Internet. *Can Med Assoc J* 2009;180(8):829–31.
14. Ginsberg J, Mohebbi MH, Patel RS, Brammer L, Smolinski MS, Brilliant L. Detecting influenza epidemics using search engine query data. *Nature* 2009;457(7232):1012–4.
15. Hulth A, Rydevik G, Linde A. Web queries as a source for syndromic surveillance. *PLoS One* 2009;4(2):e4378.
16. Eysenbach G. Infodemiology: tracking flu-related searches on the web for syndromic surveillance. *AMIA Annu Symp Proc* 2006:244–8.
17. Polgreen PM, Chen Y, Pennock DM, Nelson FD. Using Internet searches for influenza surveillance. *Clin Infect Dis* 2008;47(11):1443–8.
18. Seifter A, Schwarzwald A, Geis K, Aucott J. The utility of “Google Trends” for epidemiological research: Lyme disease as an example. *Geospat Health* 2010;4(2):135–7.
19. Gartner CE, Hall WD, Chapman S, Freeman B. Should the health community promote smokeless tobacco (snus) as a harm reduction measure? *PLoS Med* 2007;4(7):e185.
20. Molyneux A. Nicotine replacement therapy. *Br Med J* 2004;328(7437):454–6.
21. Mihalak KB, Carroll FI, Luetje CW. Varenicline is a partial agonist at alpha4beta2 and a full agonist at alpha7 neuronal nicotinic receptors. *Mol Pharmacol* 2006;70(3):801–5.
22. Trexler JC, Travis J. Nontraditional regression analyses. *Ecology* 1993;74(6):1629–37.
23. Anon. Annual estimates of the resident population for the U.S., regions, states, and Puerto Rico: April 1, 2000 to July 1, 2009 (NST-EST2009-01). 2009.
24. American Lung Association. State of tobacco control 2008. Washington DC: American Lung Association, 2009.
25. CDC. Federal and state cigarette excise taxes—U.S., 1995–2009. *MMWR Morb Mortal Wkly Rep* 2009;58(19):524–7.
26. Alamar B, Glantz SA. Effect of increased social unacceptability of cigarette smoking on reduction in cigarette consumption. *Am J Pub Health* 2006;96(8):1359–63.
27. WHO. Tobreg scientific recommendation: devices designed for the purpose of nicotine delivery to the respiratory system in which tobacco is not necessary for their operation. In: The scientific basis of tobacco product regulation: report of a WHO study group. 2009:3–11.
28. Goel S, Hofman JM, Lahaie S, Pennock DM, Watts DJ. Predicting consumer behavior with web search. *Proc Natl Acad Sci U S A* 2010;107(41):17486–90 doi:10.1073/pnas.1005962107.
29. Askatas N, Zimmermann KF. Google econometrics and unemployment forecasting. *Appl Econ Q* 2009;55(2):107–20.
30. Eysenbach G, Kohler Ch. What is the prevalence of health-related searches on the World Wide Web? Qualitative and quantitative analysis of search engine queries on the Internet. *AMIA Annu Symp Proc* 2003:225–9.
31. Eysenbach G, Köhler C. Health-related searches on the Internet. *J Am Med Assoc* 2004;291(24):2946.
32. Mokdad AH, Marks JS, Stroup DF, Gerberding JL. Actual causes of death in the U.S., 2000. *J Am Med Assoc* 2004;291(10):1238–45.
33. Reis BY, Brownstein JS. Measuring the impact of health policies using Internet search patterns: the case of abortion. *BMC Public Health* 2010;10:514.
34. LaVenture M. Using the power of googling and health informatics to improve public health practice. *Am J Prev Med* 2007;33(1):75–6.
35. Lazer D, Pentland A, Adamic L, et al. Computational social science. *Science* 2009;323(5915):721–3.
36. Health Canada. Health Canada advises Canadians not to use electronic cigarettes. Health Canada. www.hc-sc.gc.ca/ahc-asc/media/advisories-avis/_2009/2009_53-eng.php.
37. Premier of Victoria. Victorian ban on battery-powered cigarette. www.premier.vic.gov.au/newsroom/5784.html.
38. Oregon Department of Justice. Oregon Attorney General stops sale of unapproved electronic cigarettes. Oregon Department of Justice. www.doj.state.or.us/releases/2009/rel073009.shtml.
39. Bantthin C. Cheap smokes: state and federal responses to tobacco tax evasion over the Internet. *Health Matrix Clevel* 2004;14(2):325–56.
40. Ribisl KM, Williams RS, Kim AE. Internet sales of cigarettes to minors. *J Am Med Assoc* 2003;290(10):1356–9.
41. Ribisl K, Kim A, Williams R. Sales and marketing of cigarettes on the Internet: emerging threats to tobacco control and promising policy solutions. In: Reducing tobacco use: strategies, barriers, and consequences. Washington DC: National Academy Press, 2007.
42. Etter JF. Electronic cigarettes: a survey of users. *BMC Public Health* 2010;10:231.
43. King G, Keohane RO, Verba S. Designing social inquiry: scientific inference in qualitative research. Princeton NJ: Princeton University Press, 1994.

Appendix

Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.amepre.2010.12.007.