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Limited utility of detailed e-cigarette use measures: An analysis of NESARC-III

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Abstract

Introduction: The heterogeneity of e-cigarette products and e-liquids pose challenges to surveillance of e-cigarette exposure. The goal of this study was to evaluate e-cigarette use frequency, quantity, and duration measures in a national population-based survey.

Methods: Data were drawn from the 2012–2013 for the National Epidemiologic Survey on Alcohol and Related Conditions-III (n=36,309; NESARC-III). Adults who used e-cigarettes/e-liquid during the past year (18 years old; n=1,229) were asked about their age of first use, recency of use, quantity (i.e., cartridges, drops), nicotine concentration, and duration (hours). Several internal consistency parameters were compared for e-cigarette measures in past-year (n=750) and past 30-day e-cigarette users (n=472) overall, and by frequency of use (i.e., infrequent [3 days/month], non-daily [1–6 days/week], daily).

Results: There were no significant differences in quantity, nicotine concentration, or duration by frequency of use in past 30-day e-cigarette users. One-third of past 30-day and almost half of past-year users did not know the nicotine concentration of their cartridge or e-liquid. Correlations between all e-cigarette use measures were low, with the highest correlations seen between e-liquid quantity and cartridge quantity in all past 30-day users ($r=0.28$) and those reporting any e-liquid use ($r=0.40$). Cronbach's alpha and mean interitem correlations were low across all user groups.

Conclusions: Low to moderate correlation across e-cigarette measures in e-cigarette users implies low internal consistency of these measures in a population survey. Findings suggest measures such as quantity and nicotine concentration might more appropriate in samples of recent experienced e-cigarette users than in general population samples.

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Keywords

e-cigarettes; epidemiology; survey measures; nicotine; frequency; quantity

1 Introduction

Surveillance of e-cigarette use in the United States (US) began in 2010, and since that time, measures of e-cigarette use have been added to many population-based surveys that track health behaviors (Pearson, Richardson, Niaura, Vallone, & Abrams, 2012; United States Department of Health and Human Services, 2016). The goal of these measures is to understand individual and population-level use of e-cigarettes, including dose, frequency, duration of use, and likely exposure to nicotine resulting from e-cigarette use. While there have been recommendations on standardizing surveillance and evaluation of e-cigarettes to address these constructs (Amato, Boyle, & Levy, 2016; Delnevo, Gundersen, Manderski, Giovenco, & Giovino, 2017; Pearson, Hitchman, et al., 2017; Weaver et al., 2018), there are noted difficulties in measuring e-cigarette use behavior in national surveys. First, e-cigarettes are a heterogeneous category of products and there is wide variation in both the devices used and the terminology used to describe them (Echevarria & Sinha, 2017; Foulds et al., 2015; Hinds et al., 2016; Pearson, Hitchman, et al., 2017). Second, e-cigarette use varies by device type, user, and even context; this is complicated by the use of devices for consumption of non-nicotine liquids or non-nicotine substances (Miech et al., 2017). Contrary to smokers who can report consumption of discrete cigarettes, e-cigarette users may have difficulty reporting frequency of use and quantifying their use (e.g., number of puffs (Pearson, Elmasry, et al., 2017), number of milliliters of e-liquid, number of cartridges, nicotine concentration). As a result, most population surveys have focused on measuring frequency (e.g., number of days in the past 30 days) rather than quantity of e-cigarette use (e.g., puffs or times used in a day; Weaver et al., 2018). Valid and reliable survey-based e-cigarette quantity measures are needed to provide insight into product characteristics and individual factors associated with frequency and quantity of e-cigarette use as well as subsequent changes in nicotine-containing and tobacco product use (Giovenco, Lewis, & Delnevo, 2014).

The National Epidemiologic Survey on Alcohol and Related Conditions-III (NESARC-III), a major US national survey focusing on substance use, collects data on both frequency and quantity of use, with quantity of e-cigarette use reflecting consumption of disposable e-cigarettes, cartridges, or e-liquid on days of use (Grant et al., 2014). Although this survey was conducted in 2012–2013, the e-cigarette measures contain both similar and more detailed questions than the most updated version of the National Institute on Health supported web-based catalog standardized protocol for measuring phenotypes and exposures relevant to clinical research (i.e., PhenX Toolkit; <http://www.phenxtoolkit.org>). The PhenX Toolkit ‘Use of Tobacco Products Protocol’ uses consensus questions on e-cigarette use from The Population Assessment of Tobacco and Health (PATH) Study, another US national survey (US Department of Health and Human Services, 2017).

As seen in studies of e-cigarette users, increased frequency of use is associated with use of refillable and rechargeable devices (Coleman et al., 2017; Hitchman, Brose, Brown, Robson, & McNeill, 2015). In lab studies, participants with prior e-cigarette experience have greater plasma nicotine concentrations at various doses of nicotine compared to participants who are e-cigarette naïve (Hiler et al., 2017). We expected that more experienced e-cigarette users (i.e., those who had used for a longer duration of time) would report greater use of e-liquid/cartridge quantity, but we did not have a hypothesis about the nicotine concentration of that liquid, given earlier work showing that experienced users can titrate their nicotine exposure even with low nicotine concentration liquids (Wagener et al., 2017). A connection has also been made between cigarette smoking cessation and frequency of e-cigarette use (Brose, Hitchman, Brown, West, & McNeill, 2015; Delnevo et al., 2016; Farsalinos & Niaura, 2019; Giovenco & Delnevo, 2018; Hitchman et al., 2015), suggesting that more frequent users may achieve an adequate nicotine dose (by some combination of greater quantity of use, more efficient nicotine delivery with a more advanced device, and/or greater e-cigarette nicotine concentration) to replace cigarettes with e-cigarettes.

The goal of this study was to use the most recent wave of the NESARC to examine the internal consistency of e-cigarette measures. An additional goal was to evaluate to what degree current e-cigarette users can report details about their use. We hypothesized that e-liquid and/or cartridge quantity, nicotine concentration, and duration of use would be more strongly correlated among daily past 30-day e-cigarette users than among infrequent or non-daily users.

2 Methods

2.1 Data Source & Sample

Data for this study come from the NESARC-III, a nationally representative survey of US non-institutionalized civilian adults (aged 18 years or older), including residents of selected group quarters (e.g., group homes, dormitories for workers). Individuals were randomly selected by multistage probability sampling starting with individual counties or groups of contiguous counties for primary sampling units, then by groups of census-defined blocks for secondary sampling units, and finally households in the secondary sampling units for tertiary sampling units. Participants were interviewed from April 2012 through June 2013 following institutional review board approved protocols (n=36,309). Detailed NESARC-III methods have been described elsewhere (Grant et al., 2014).

Consistent with existing studies on current e-cigarette users, these analyses focused on respondents who used e-cigarettes/e-liquid during the past year (n=1,240). Individuals who had used in the past 12 months were divided into two mutually exclusive groups: past 30-day (n=472) or past-year users (n=750).

2.2 Measures

The NESARC-III tobacco and nicotine use (TUD) section includes items about experiences with tobacco and nicotine (see Table 1 for a complete list of measures). Lifetime e-cigarette users had ever used an e-cigarette (assessed by the “ever use” item). Ever users were then

asked about age of first use, use in the past year, and recency of use (e.g., hours, days, weeks, months, or years ago). Respondents indicated what age they started using e-cigarettes (range: 14–78 years old). Recency of use was recoded as days since last use and combined with past year use to create two categories of users: 1) those who had used an e-cigarette in the past 12 months as defined by the past year question, but not in the past 30 days; and 2) those who had used an e-cigarette in the past year and in the past 30 days. There was not an item to directly assess past 30-day e-cigarette use (e.g., have you used e-cigarettes in the past 30 days?) in the NESARC-III.

Past year users were also asked about their frequency of e-cigarette use in the past year, with response options: every day, 5 to 6 days per week, 3 to 4 days per week, 1 to 2 days per week; 2 to 3 days a month; and once a month or less. We used this variable to further classify frequency of e-cigarette use in the past 30-day e-cigarette users, consistent with Coleman and colleagues (2017). Past 30-day e-cigarette users were designated as infrequent (used up to 3 days a month), non-daily (used 1–6 days per week), and daily e-cigarette users (used every day).

In the questionnaire, adults who used e-cigarettes/e-liquid during the past year were also asked their quantity of use (i.e., cartridges, drops), nicotine concentration, duration of use, and ever daily use (Table 1). Quantity of use was measured as the usual number of cartridges or drops of e-liquid used on the days participants used either e-cigarette cartridges or e-liquid in the past year. The concentration of nicotine was reported in their most recently-used e-cigarette cartridge or e-liquid (i.e., 0, 6, 8, 11, 12, 14, 16, 18, 24, 36 mg, or another specified quantity). Duration was how long participants had used this amount of e-cigarettes/e-liquid (range: 0–183 months). Participants were also asked if they ever used e-cigarettes daily. For all e-cigarette measures questions, respondents had the option to choose “Unknown” if they did not know how to respond. Although frequency and quantity of use questions ask about the past year or the year “right before you stopped” (see Table 1), our analyses used them as past-year measures because we only included e-cigarette users who used in the past 12 months.

Length of use was derived from age of first use and age at interview by subtracting a respondent’s age when he/she used e-cigarettes/e-liquid for the first time from the his/her current age [range: 0–8 years]. Finally, e-cigarette users were categorized into groups by their cartridge/e-liquid device use due to the aforementioned heterogeneity in device types (i.e., cartridge only, e-liquid only, both cartridges and e-liquid, unknown) and the association between device type and behavioral outcomes (Hitchman et al., 2015). Paired with frequency of e-cigarette use, device type has been associated with behavioral outcomes such as smoking cessation (Hitchman et al., 2015).

Sociodemographic characteristics included age group, sex, race/ethnicity, and education. Race/ethnicity was categorized as non-Hispanic white, non-Hispanic black or African American, non-Hispanic other (i.e., Asian, American-Indian or Alaskan Native, other, multirace), and Hispanic. Other current tobacco use was also collected (e.g., cigarettes, cigars, pipes, and snuff/chewing tobacco) and was defined similarly to current e-cigarette use (i.e., use in the past month defined by “When was the most recent time you used

[product]?”). Background characteristics by past 30-day e-cigarette use frequency in this sample are presented elsewhere (Parker & Villanti, 2019).

2.3 Statistical Analyses

Weighted percentages of e-cigarette users were estimated by sociodemographic characteristics, other tobacco use, and e-cigarette measures using Stata, version 14 (Stata Corp, 2015), which addressed the NESARC-III complex sampling design with the ‘svy’ procedure. Measures of e-cigarette quantity (i.e., cartridge or e-liquid), nicotine concentration, and duration of use were conceived of as measuring the underlying construct of e-cigarette use. We hypothesized that correlations between these measures would increase with a more established pattern of use, measured as greater frequency of use. As such, unweighted Pearson correlations were used to gauge the strength of the associations between questionnaire items. Cronbach’s α coefficient and interitem correlations of these e-cigarette use measures were compared between past 30-day users overall and by frequency of use to assess internal consistency of the measures. For multidimensional measures, α suggests the degree to which items measure the same underlying construct (Sijtsma, 2009). Cronbach’s α coefficient is widely used for assessing internal consistency of questionnaires; better alternatives are known, but rarely used (Trizano-Hermosilla & Alvarado, 2016).

3 Results

Past 30-day e-cigarette use was highest in non-Hispanic whites, those aged 25–34, current cigarette smokers, and those with some college education (Table 2). Among past 30-day e-cigarette users, 81.4% were also past 30-day cigarette users, 5.7% were past 30-day cigar users, 4.8% were past 30-day snuff/chewing tobacco users, and 1.1% were past 30-day pipe users. Respondent sociodemographic characteristic and tobacco use estimates were similar for both past-year (but not in the past-month) and past 30-day e-cigarette users (Table 2).

The mean length of use for past 30-day e-cigarette users was 9.2 months (Table 3). More than 60% of infrequent users reporting first use in young adulthood (29.1% at ages 18–24 and 30.6% at ages 25–34) and more than 70% of daily users reporting first use after age 35. Past-year e-cigarette users were similar to past 30-day users for both length of use and age of first use (p -values>0.05). Recency of use varied by frequency of past 30-day e-cigarette use, with 50.8% of infrequent users stating their last e-cigarette use was 168–480 hours (7–20 days) ago and 48.8% of daily users having used their e-cigarette within the past hour (Table 3).

Of the 472 past 30-day e-cigarette users, 387 answered both quantity questions (i.e., number of e-cigarette cartridges and drops of e-liquid used), with most past 30-day users reporting zero drops of e-liquid and one e-cigarette cartridge in the past year ($n=260$). The majority of past 30-day e-cigarette users used cartridges and not e-liquid (75.0%), with 5.7% of respondents not knowing whether they used cartridges or e-liquid (Table 3). There were no significant differences in type of product used (cartridge vs. e-liquid) by frequency of use, though a lower proportion of daily (70.6%) users were cartridge-only users compared to 82.9% of past-year users (p -value<0.05; Table 3).

For quantity of e-cigarette use, 6.0% of past-year and 5.9% of past 30-day users reported an “Unknown” number of cartridges and about 5% reported an “Unknown” number of drops of e-liquid (5.3% of past-year vs. 5.1% of past 30-day e-cigarette users; Table 3). Though the number of usual cartridges did not differ significantly by frequency of use for past 30-day e-cigarette users, daily users reported 2.9 cartridges, compared to 1.2 cartridges reported by infrequent users ($p\text{-value}>0.05$; Table 3). There was, however, a significant difference in the number of e-liquid drops for daily users compared to infrequent users (18.5 drops vs. 3.6 drops; $p\text{-value}<0.05$).

Overall, 33.0% of past 30-day e-cigarette users did not know their usual nicotine concentration, which differed significantly by frequency of use such that 45.9% of infrequent users reported the nicotine concentration as “Unknown” compared to 20.3% of daily users ($p<0.05$; Table 3). Almost half of past-year users also reported they did not know the nicotine concentration used in their device (47.9%). In addition, ever daily e-cigarette use was significantly higher among non-daily users (40.3%) compared to infrequent users (9.3%; $p\text{-value}<0.05$; Table 3). Approximately one-third of past-year e-cigarette users were ever daily e-cigarette users (33.1%).

In examining internal consistency parameters, among past 30-day e-cigarette users the overall α was low (0.34), which increased by use frequency ($\alpha[\text{infrequent}]=0.10$, $\alpha[\text{non-daily}]=0.20$, $\alpha[\text{daily}]=0.37$; data not shown in a table). Interitem correlation followed a similar pattern at 0.11 overall, 0.03 for infrequent e-cigarette users, 0.06 for non-daily users, and 0.13 for daily users. Estimates for past-year users were even lower (overall $\alpha=0.11$ and interitem correlation=0.03). For type of e-cigarette use, parameters were higher for individuals who used e-liquid compared to those who used cartridges ($\alpha[\text{cartridges}]=0.08$ and interitem correlation=0.02 versus $\alpha[\text{any e-liquid}]=0.25$ and interitem correlation=0.08).

Table 4 presents the correlations between e-cigarette use measures by type of e-cigarette use for (1) all past-year e-cigarette users, (2) all past 30-day e-cigarette users, and (3) past 30-day e-cigarette users by frequency of use. Type of e-cigarette use is categorized by users who used cartridges, e-liquid, or both (first column) and those with any e-liquid use (second column). Correlations between all e-cigarette use measures were low ($r<0.4$), with the majority of correlations being $r<0.2$ for past 30-day e-cigarette users and lower for past-year users ($r<0.1$). Overall, the strongest positive correlations were between cartridge quantity and e-liquid quantity ($r=0.28$ for all past 30-day e-cigarette users and $r=0.40$ for any e-liquid users). In all e-cigarette users, there was an inverse relationship between nicotine concentration and both measures of quantity (i.e., cartridge quantity and e-liquid quantity). Overall, there was no consistent pattern in Pearson correlations between measures when comparing across categories of use frequency.

Among any e-liquid users, some moderate negative correlations should be noted. For infrequent users, the correlation between nicotine concentration and cartridge quantity was $r=-0.39$, which is on par with the magnitude seen between e-liquid quantity and cartridge quantity in daily users (Table 4). In addition, for non-daily users, the correlation between duration and cartridge quantity was $r=-0.27$.

4 Discussion

Internal consistency is often used to determine which items should be included in a survey and typically refers to items' interrelatedness (Sijtsma, 2009). Internal consistency is associated with interitem correlation, validity, and reliability. Almost all of our correlations and internal consistency estimates fell below typical cut-offs for evaluating survey measures. Guidelines suggest that items with correlations below 0.30 are not sufficiently related and items with correlations above 0.70 are redundant (Ferketich, 1991). Furthermore, the number of respondents who chose "Unknown" for several key measures shows that evaluating constructs of e-cigarette use remains a challenge at the population-level even with a detailed questionnaire section. There were a few items with responses consistent with our expectations based on patterns of e-cigarette use. First, for daily users, their recency of use was within the past hour, while it was much longer for infrequent users. Second, daily users reported significantly higher consumption of e-liquid drops than infrequent users. Third, there was a consistent inverse relationship between nicotine concentration and both measures of quantity. Finally, while there was no consistent pattern of the correlations between measures when comparing across categories of use frequency overall, measures of internal consistency increased with use frequency although they were low.

Past-year e-cigarette users had lower correlations and internal consistency measures than past 30-day users, indicating that recency of use may be an important consideration in collecting e-cigarette measures. When comparing by cartridge or e-liquid, a proxy for e-cigarette device type, correlations between quantity measures and duration of use were stronger among daily e-liquid versus infrequent or non-daily e-liquid users. This suggests that more experienced users have fewer problems reporting quantity of e-cigarette use than inexperienced users. However, we acknowledge that some individuals may use e-cigarettes in lower quantities more frequently and vice versa.

Internal consistency parameters were also stronger for e-liquid versus cartridge users. Qualitative studies have found that individuals sometimes have difficulty quantifying how much e-liquid used (Cooper, Harrell, & Perry, 2016; Hinds et al., 2016), and including "Unknown" as an answer allows less established e-cigarette users to answer the questions accurately (Hinds et al., 2016). However, this limited our ability to evaluate correlations across measures because we effectively chose to treat these responses as 'missing' and thus, excluded them from our correlation analyses.

Low correlations and internal consistency measures may be due in part to the fact that these data were collected in 2012–2013. Although the questionnaire and other surveys that measure e-cigarettes have not been updated (e.g., PATH Study), awareness and use of e-cigarettes increased between 2010–13 following their introduction to the US market in 2007, and e-cigarette use practices have changed, with increasing use of tanks/e-liquid and less cartridge use (King, Patel, Nguyen, & Dube, 2015). At the time of the NESARC-III, there were a variety of different e-cigarette brands in the market, with the top brands in 2012 offering cigalike products and growth in retail sales driven by the brands blu and NJOY at the beginning of 2013 (Huang et al., 2018; Zhu et al., 2014). As such, the fact that the majority of these past 30-day users reported use of a single cartridge may also explain why

these measures of quantity, concentration, and duration were not correlated. Still, these findings provide valuable information about e-cigarette measures in a national sample especially since survey questions have not yet been updated.

There are several strengths and limitations to the study. We used nationally representative data to show novel relationships between detailed e-cigarette survey measures including frequency and quantity of use. Other surveys still use similar questions for assessing e-cigarette use (e.g., PATH study; US Department of Health and Human Services, 2017), so addressing the utility of the measures is paramount for future waves. However, the NESARC-III provided no preamble about e-cigarettes, and there were limitations to the survey questions. For example, respondents were not asked directly about whether or not they had used in the past 30 days, which may have led to unreliable results for past 30-day e-cigarette users. The Phen-X toolkit includes questions specifically about past 30 day e-cigarette use, so omitting this designation limits the utility of the remaining e-cigarette questions that relate to past-year use. In addition, specific nicotine concentration values were listed rather than ranges, there was no question on the type of e-cigarette product with subgroup-relevant questions (Pearson, Hitchman, et al., 2017), and the questionnaire only allowed us to consider pre-specified frequency categories, which precluded us from dividing users by other frequency cut-offs (e.g., 5 days of use/month) that demonstrate differences in e-cigarette users (Amato et al., 2016; Amato, Boyle, & Levy, 2017).

Taken together, low to moderate correlation across all e-cigarette items and the high proportion of unknown responses on nicotine concentration suggest low internal consistency of these measures in a large population sample. Findings suggest detailed measures of e-cigarette quantity may be more appropriate for studies of recent experienced e-cigarette users rather than large population samples of ever users as use patterns highly vary, even within one year (Coleman et al., 2018). In addition, as recommended by others, standardized measures of e-cigarette use are needed for population surveys to better quantify e-cigarette use and exposure (Delnevo et al., 2016; Pearson, Hitchman, et al., 2017; Weaver et al., 2018). Minimum core measures for population surveys recommended by Pearson et al., for example, reflect ever use (“Yes;” “No;” “Don’t know”) and frequency of use among ever users (i.e., “How often do you currently use an e-cigarette or vaping device?” with response choices: Daily or almost daily; Less than daily, but at least once a week; Less than weekly, but at least once a month; Less than monthly; Not at all; and Don’t know; Pearson, Hitchman, et al., 2017). Future waves of the NESARC-III should be examined to determine whether internal consistency of these measures has changed with greater awareness and use of e-cigarettes at the population level.

References

- Amato MS, Boyle RG, & Levy D (2016). How to define e-cigarette prevalence? Finding clues in the use frequency distribution. *Tobacco Control*, 25(E1), e24–e29. 10.1136/tobaccocontrol-2015-052236 [PubMed: 26085124]
- Amato MS, Boyle RG, & Levy D (2017). E-cigarette use 1 year later in a population-based prospective cohort. *Tobacco Control*, 26(e2), e92–e96. 10.1136/tobaccocontrol-2016-053177 [PubMed: 27807298]

- Brose LS, Hitchman SC, Brown J, West R, & McNeill A (2015). Is the use of electronic cigarettes while smoking associated with smoking cessation attempts, cessation and reduced cigarette consumption? A survey with a 1-year follow-up. *Addiction* (Abingdon, England), 110(7), 1160–1168. 10.1111/add.12917
- Coleman BN, Rostron B, Johnson SE, Ambrose BK, Pearson J, Stanton CA, ... Hyland A (2017). Electronic cigarette use among US adults in the Population Assessment of Tobacco and Health (PATH) Study, 2013–2014. *Tobacco Control*, tobaccocontrol-2016–053462. 10.1136/tobaccocontrol-2016-053462
- Coleman BN, Rostron B, Johnson SE, Persoskie A, Pearson J, Stanton C, ... Hyland A (2018). Transitions in electronic cigarette use among adults in the Population Assessment of Tobacco and Health (PATH) Study, Waves 1 and 2 (2013–2015). *Tobacco Control*. 10.1136/tobaccocontrol-2017-054174
- Cooper M, Harrell MB, & Perry CL (2016). A Qualitative Approach to Understanding Real-World Electronic Cigarette Use: Implications for Measurement and Regulation. *Preventing Chronic Disease*, 13 10.5888/pcd13.150502
- Delnevo CD, Giovenco DP, Steinberg MB, Villanti AC, Pearson JL, Niaura RS, & Abrams DB (2016). Patterns of electronic cigarette use among adults in the United States. *Nicotine & Tobacco Research*, 18(5), 715–719. 10.1093/ntr/ntv237 [PubMed: 26525063]
- Delnevo CD, Gundersen DA, Manderski MTB, Giovenco DP, & Giovino GA (2017). Importance of Survey Design for Studying the Epidemiology of Emerging Tobacco Product Use Among Youth. *American Journal of Epidemiology*, 186(4), 405–410. 10.1093/aje/kwx031 [PubMed: 28369184]
- Echevarria C, & Sinha IP (2017). Heterogeneity in the measurement and reporting of outcomes in studies of electronic cigarette use in adolescents: a systematic analysis of observational studies. *Tobacco Control*, 26(3), 247–253. 10.1136/tobaccocontrol-2015-052881 [PubMed: 27129981]
- Farsalinos K, & Niaura R (2019). E-cigarettes and smoking cessation in the United States according to frequency of e-cigarette use and quitting duration: analysis of the 2016 and 2017 National Health Interview Surveys. *Nicotine & Tobacco Research*. 10.1093/ntr/ntz025
- Ferketich S (1991). Focus on psychometrics. Aspects of item analysis. *Research in Nursing & Health*, 14(2), 165–168. [PubMed: 2047538]
- Foulds J, Veldheer S, Yingst J, Hrabovsky S, Wilson SJ, Nichols TT, & Eissenberg T (2015). Development of a Questionnaire for Assessing Dependence on Electronic Cigarettes Among a Large Sample of Ex-Smoking E-cigarette Users. *Nicotine & Tobacco Research*, 17(2), 186–192. 10.1093/ntr/ntu204 [PubMed: 25332459]
- Giovenco DP, & Delnevo CD (2018). Prevalence of population smoking cessation by electronic cigarette use status in a national sample of recent smokers. *Addictive Behaviors*, 76, 129–134. 10.1016/j.addbeh.2017.08.002 [PubMed: 28802179]
- Giovenco DP, Lewis MJ, & Delnevo CD (2014). Factors Associated with E-cigarette Use: A National Population Survey of Current and Former Smokers. *American Journal of Preventive Medicine*, 47(4), 476–480. 10.1016/j.amepre.2014.04.009 [PubMed: 24880986]
- Grant BF, Chu A, Sigman R, Amsbary M, Kali J, Sugawara Y, ... Goldstein R (2014). Source and Accuracy Statement: National Epidemiologic Survey on Alcohol and Related Conditions-III (NESARC-III). Rockville, MD: National Institute on Alcohol Abuse and Alcoholism Retrieved from https://www.niaaa.nih.gov/sites/default/files/NESARC_Final_Report_FINAL_1_8_15.pdf
- Hiler M, Breland A, Spindle T, Maloney S, Lipato T, Karaoghlanian N, ... Eissenberg T (2017). Electronic Cigarette User Plasma Nicotine Concentration, Puff Topography, Heart Rate, and Subjective Effects: Influence of Liquid Nicotine Concentration and User Experience. *Experimental and Clinical Psychopharmacology*, 25(5), 380–392. 10.1037/pha0000140 [PubMed: 29048187]
- Hinds JT, Loukas A, Chow S, Pasch KE, Harrell MB, Perry CL, ... Wackowski OA (2016). Using Cognitive Interviewing to Better Assess Young Adult E-cigarette Use. *Nicotine & Tobacco Research*, 18(10), 1998–2005. 10.1093/ntr/ntw096 [PubMed: 27029822]
- Hitchman SC, Brose LS, Brown J, Robson D, & McNeill A (2015). Associations Between E-Cigarette Type, Frequency of Use, and Quitting Smoking: Findings From a Longitudinal Online Panel Survey in Great Britain. *Nicotine & Tobacco Research*, 17(10), 1187–1194. 10.1093/ntr/ntv078 [PubMed: 25896067]

- Huang J, Duan Z, Kwok J, Binns S, Vera LE, Kim Y, ... Emery SL (2018). Vaping versus JUULing: how the extraordinary growth and marketing of JUUL transformed the US retail e-cigarette market. *Tobacco Control*, tobaccocontrol-2018-054382. 10.1136/tobaccocontrol-2018-054382
- King BA, Patel R, Nguyen KH, & Dube SR (2015). Trends in Awareness and Use of Electronic Cigarettes Among US Adults, 2010–2013. *Nicotine & Tobacco Research*, 17(2), 219–227. 10.1093/ntr/ntu191 [PubMed: 25239961]
- Miech RA, Johnston LD, O'Malley PM, Bachman JG, Schulenberg JE, & Patrick ME (2017). Monitoring the Future national survey results on drug use, 1975–2017: Volume I, Secondary school students (p. 566). Ann Arbor, MI: Institute for Social Research, The University of Michigan.
- Parker MA, & Villanti AC (2019). Patterns and frequency of current e-cigarette use in United States adults. *Substance Use & Misuse*. 1–7 10.1080/10826084.2019.1626433
- Pearson JL, Elmasry H, Das B, Smiley SL, Rubin LF, DeAtley T, ... Abrams DB (2017). Comparison of Ecological Momentary Assessment Versus Direct Measurement of E-Cigarette Use With a Bluetooth-Enabled E-Cigarette: A Pilot Study. *JMIR Research Protocols*, 6(5). 10.2196/resprot.6501
- Pearson JL, Hitchman SC, Brose LS, Bauld L, Glasser AM, Villanti AC, ... Cohen JE (2017). Recommended core items to assess e-cigarette use in population-based surveys. *Tobacco Control*. 10.1136/tobaccocontrol-2016-053541
- Pearson JL, Richardson A, Niaura RS, Vallone DM, & Abrams DB (2012). e-Cigarette Awareness, Use, and Harm Perceptions in US Adults. *American Journal of Public Health*, 102(9), 1758–1766. 10.2105/AJPH.2011.300526 [PubMed: 22813087]
- Sijtsma K (2009). On the Use, the Misuse, and the Very Limited Usefulness of Cronbach's Alpha. *Psychometrika*, 74(1), 107–120. 10.1007/s11336-008-9101-0 [PubMed: 20037639]
- Stata Corp. (2015). *Stata Statistical Software: Release 14 (Version 14)*. College Station, TX: Stata Corp LP.
- Trizano-Hermosilla I, & Alvarado JM (2016). Best Alternatives to Cronbach's Alpha Reliability in Realistic Conditions: Congeneric and Asymmetrical Measurements. *Frontiers in Psychology*, 7 10.3389/fpsyg.2016.00769
- United States Department of Health and Human Services. (2016). *E-cigarette Use Among Youth and Young Adults: A Report of the Surgeon General*. Rockville, MD: Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health Retrieved from <https://www.surgeongeneral.gov/library/2016ecigarettes/index.html>
- United States Department of Health and Human Services, National Institutes of Health, National Institute on Drug Abuse, & Food and Drug Administration, Center for Tobacco Products. (2017). *Population Assessment of Tobacco and Health (PATH) Study Public-Use Files: User Guide* (No. HHSN271201100027C) (p. 133). Rockville, MD: Inter-University Consortium for Political and Social Research.
- Wagener TL, Floyd EL, Stepanov I, Driskill LM, Frank SG, Meier E, ... Queimado L (2017). Have combustible cigarettes met their match? The nicotine delivery profiles and harmful constituent exposures of second-generation and third-generation electronic cigarette users. *Tobacco Control*, 26(e1), e23–e28. 10.1136/tobaccocontrol-2016-053041 [PubMed: 27729564]
- Weaver SR, Kim H, Glasser AM, Sutfin EL, Barrington-Trimis J, Payne TJ, ... Loukas A (2018). Establishing consensus on survey measures for electronic nicotine and non-nicotine delivery system use: Current challenges and considerations for researchers. *Addictive Behaviors*, 79, 203–212. 10.1016/j.addbeh.2017.11.016 [PubMed: 29173942]
- Zhu S-H, Sun JY, Bonnevie E, Cummins SE, Gamst A, Yin L, & Lee M (2014). Four hundred and sixty brands of e-cigarettes and counting: implications for product regulation. *Tobacco Control*, 23(Suppl 3), iii3–iii9. 10.1136/tobaccocontrol-2014-051670 [PubMed: 24935895]

HIGHLIGHTS

- There was low correlation between e-cigarette measures in past 30-day users.
- Correlation between e-cigarette measures did not increase by frequency of use.
- A large proportion of users did not know their product's nicotine concentration.
- Detailed e-cigarette measures may be appropriate for studies of experienced users.

Table 1.

Survey questions and response options for past year e-cigarette/e-liquid users; 2012–2013 National Epidemiologic Survey on Alcohol and Related Conditions-III

Measure	Survey question	Response options
Ever use	In your entire life, have you ever used E-Cigarettes/E-Liquid?	Yes/No
Age of first use	About how old were you when you first used E-Cigarettes or E-Liquid?	Range 14–78
Past year use	During the last 12 months, that is, since last (<i>month one year ago</i>), did you use at least one E-Cigarette cartridge/4 drops of E-Liquid?	Yes/No
Recency of use	When was the MOST RECENT time you used E-Cigarettes/E-Liquid	Respondents could answer in hours, days, weeks, months, years, or a combination of these responses.
Frequency of use	About how often did you USUALLY use E-Cigarettes/E-Liquid in the past year/in the year right before you stopped?	Every day; 5 to 6 days a week; 3 to 4 days a week; 1 to 2 days a week; 2 to 3 days a month; Once a month or less
Quantity of use	On the days that you used E-Cigarettes/E-Liquid in the past year/in the year right before you stopped, about how many E-Cigarette cartridges did you USUALLY use?	Range 1–61 cartridges/“did not use e-cigarettes”
	On the days that you used E-Cigarettes/E-Liquid in the past year/in the year right before you stopped, about how many drops of E-Liquid did you USUALLY use?	Range 1–80 drops of e-liquid/“did not use e-liquid”
Nicotine concentration	During that time, about how many milligrams of nicotine were in your E-Cigarette cartridge or E-Liquid?	0 mg; 6 mg; 8 mg; 11 mg; 12 mg; 14 mg; 16 mg; 18 mg; 24 mg; 36 mg; Other (specify)
Duration of use	For how long have you used this amount?	Respondents could answer in hours, days, weeks, months, years, or a combination of these responses.
Ever daily use	Did you ever use E-cigarettes or E-Liquid every day?	Yes/No

Table 2.

Sociodemographic characteristics of e-cigarette users by recency of use (% , 95% Confidence Interval). Data from the 2012–2013 National Epidemiologic Survey on Alcohol and Related Conditions-III.^a

	Past-year e-cigarette users ^b (n = 750)	Past 30-day e-cigarette users (n = 472)
Male	55.7 (51.4, 59.9)	48.1 (42.6, 53.6)
Race/ethnicity		
White, non-Hispanic	77.3 (73.2, 80.9)	77.9 (73.6, 81.7)
Black, non-Hispanic	6.6 (5.1, 8.7)	6.1 (4.4, 8.6)
Other, non-Hispanic	7.2 (5.0, 10.4)	6.7 (4.2, 10.5)
Hispanic	8.8 (6.8, 11.4)	9.2 (6.9, 12.4)
Age, years		
18–24	22.7 (19.3, 26.5)	20.4 (16.1, 25.7)
25–34	30.6 (26.7, 34.9)	24.2 (20.2, 28.8)
35–44	19.2 (16.0, 22.8)	19.6 (15.6, 24.3)
45–54	15.3 (12.7, 18.4)	19.2 (14.1, 25.7)
55+	12.2 (9.3, 15.7)	16.5 (13.0, 20.6)
Education		
Less than high-school	11.9 (9.4, 14.8)	12.2 (9.2, 16.0)
High-school diploma	35.6 (32.0, 39.4)	30.2 (25.3, 35.6)
Some college	41.3 (36.9, 45.9)	43.9 (38.3, 49.7)
Bachelor's degree or more	11.2 (8.4, 14.8)	13.7 (10.2, 18.2)
Current cigarette smoker	85.4 (82.1, 88.2)	81.4 (77.3, 84.9)
Current cigar smoker	5.4 (3.7, 7.8)	5.7 (3.6, 8.8)
Current pipe smoker	2.1 (1.2, 3.8)	1.1 (0.4, 2.6)
Current snuff/chewing tobacco user	5.0 (3.4, 7.3)	4.8 (2.5, 9.0)

^aNumbers may not sum to 100% due to rounding.

^bPast-year users exclude those who reported e-cigarette use in the past 30 days.

Table 3.

Characteristics of e-cigarette use among past-year e-cigarette users (weighted %, 95% Confidence Intervals; n=472), 2012–2013 National Epidemiologic Survey on Alcohol and Related Conditions-III.^a

Measure	Past-year e-cigarette users (n=750)	All past 30-day e-cigarette users (n=472)	Infrequent e-cigarette users (n=188)	Non-daily e-cigarette users (n=146)	Daily e-cigarette users (n=138)
Length of use, months ^b	11.1 (10.0, 12.1)	9.2 (7.5, 10.9)	8.1 (5.6, 10.7)	10.3 (7.7, 13.0)	9.2 (6.7, 11.8)
Age of first use, years					
17–24 ^c	25.9 (22.4, 29.8)	22.0 (17.5, 27.4)	29.1 (20.7, 39.2)	20.1 (13.4, 29.0)	15.0 (9.4, 23.1)
25–34	29.5 (25.7, 33.6)	23.4 (19.4, 27.8)	30.6 (23.0, 39.4)	23.5 (17.3, 31.1)	13.7 (8.5, 21.4)
35–44	18.9 (15.7, 22.5)	21.1 (16.9, 26.0)	17.3 (12.2, 24.1)	17.3 (11.7, 25.0)	30.3 (21.1, 41.3)
45–54	15.4 (12.6, 18.6)	18.1 (13.2, 24.4)	11.0 (6.6, 17.7)	25.3 (16.6, 36.5)	19.5 (12.4, 29.3)
55+	10.3 (7.7, 13.7)	15.4 (12.0, 19.5)	12.1 (7.9, 18.0)	13.8 (8.3, 22.1)	21.5 (14.7, 30.3)
Recency of use					
1 hour		20.5 (17.1, 24.4)	8.8 (4.9, 15.2)	9.4 (4.7, 17.7)	48.6 (39.9, 57.4)
2–24 hours		26.0 (21.6, 30.9)	15.4 (10.0, 22.8)	27.4 (19.6, 36.8)	38.2 (29.1, 48.3)
48–144 hours (2–6 days)		15.2 (11.8, 19.4)	16.2 (11.1, 23.1)	22.3 (15.4, 31.2)	5.8 (2.1, 14.8)
168–480 hours (7–20 days)		33.2 (28.9, 37.8)	50.8 (43.2, 58.3)	35.9 (26.4, 46.7)	7.0 (3.3, 14.2)
504–672 hours (21–28 days)		5.1 (3.2, 8.2)	8.8 (4.8, 15.6)	5.0 (2.1, 11.5)	0.4 (0.1, 2.7)
>672 hours (28 days)	100.0				
Type of e-cigarette device					
Cartridge only	82.9 (78.4, 86.7)	75.0 (69.2, 80.0)	81.3 (73.3, 87.4)	71.9 (61.9, 80.1)	70.6 (63.4, 76.9)
E-liquid only	3.2 (1.8, 5.4)	7.5 (4.9, 11.1)	5.7 (2.6, 11.8)	7.8 (3.4, 16.8)	9.3 (5.7, 15.0)
Both cartridges and e-liquid	8.0 (5.9, 10.7)	11.8 (9.2, 15.1)	6.7 (4.1, 10.7)	15.4 (9.8, 23.3)	14.1 (9.6, 20.2)
Unknown	5.9 (3.7, 9.3)	5.7 (3.8, 8.6)	6.3 (3.3, 11.7)	4.9 (1.9, 12.1)	6.0 (3.3, 10.7)
Quantity of use, cartridges ^d	1.3 (1.2, 1.5)	1.7 (1.2, 2.2)	1.2 (1.0, 1.3)	1.2 (1.1, 1.4)	2.9 (1.3, 4.5)
Unknown	6.0 (3.7, 9.4)	5.9 (3.9, 8.9)	6.4 (3.4, 12.0)	5.2 (2.1, 12.7)	6.1 (3.3, 10.8)
Quantity of use, drops of e-liquid ^e	0.3 (0.2, 0.5)	13.8 (6.6, 20.9)	3.6 (2.0, 5.2)	15.4 (0.0, 31.2)	18.5 (11.5, 25.6)
Unknown	5.3 (3.3, 8.4)	5.1 (3.4, 7.7)	5.4 (2.9, 10.0)	4.5 (1.8, 11.1)	5.5 (3.1, 9.6)
Nicotine concentration, average mg	11.9 (11.1, 12.6)	12.2 (11.4, 13.0)	11.0 (9.7, 12.3)	11.5 (10.1, 13.0)	14.0 (12.4, 15.5)
0 mg	4.9 (3.1, 7.4)	4.2 (2.7, 6.4)	4.2 (2.0, 8.6)	3.7 (1.6, 8.4)	4.6 (2.1, 10.0)

Measure	Past-year e-cigarette users (n=750)	All past 30-day e-cigarette users (n=472)	Infrequent e-cigarette users (n=188)	Non-daily e-cigarette users (n=146)	Daily e-cigarette users (n=138)
6 mg	14.0 (11.1, 17.5)	15.0 (11.7, 19.0)	11.9 (7.4, 18.6)	18.3 (12.1, 26.6)	15.4 (9.7, 23.5)
8 mg	10.9 (8.4, 13.9)	9.8 (7.1, 13.4)	8.6 (5.3, 13.7)	9.3 (5.2, 16.1)	12.0 (6.7, 20.4)
11 mg	2.5 (1.5, 4.0)	4.4 (2.7, 7.1)	3.4 (1.5, 7.5)	6.1 (2.9, 12.3)	3.7 (1.4, 9.6)
12 mg	3.5 (2.4, 5.1)	7.6 (4.9, 11.6)	4.6 (2.1, 10.1)	9.7 (5.2, 17.6)	9.0 (3.7, 20.6)
14 mg	2.8 (1.7, 4.6)	2.4 (1.3, 4.6)	4.4 (1.9, 9.7)	1.7 (0.6, 4.7)	0.6 (0.2, 2.5)
16 mg	2.9 (1.6, 5.1)	5.8 (3.2, 10.4)	4.2 (1.9, 8.9)	7.6 (2.3, 22.6)	6.1 (2.4, 14.9)
18 mg	4.6 (3.0, 6.9)	9.2 (6.5, 12.9)	7.6 (3.8, 14.6)	6.1 (2.4, 14.9)	14.7 (9.5, 22.2)
24 mg	4.3 (2.9, 6.5)	5.0 (3.2, 7.6)	0.7 (0.2, 2.4)	3.4 (1.3, 9.0)	12.3 (7.6, 19.4)
36 mg	1.3 (0.6, 2.7)	1.0 (0.4, 2.3)	0.5 (0.1, 3.3)	1.4 (0.4, 4.6)	1.2 (0.3, 5.4)
Other	0.5 (0.2, 1.5)	2.7 (1.4, 5.1)	4.1 (1.7, 9.6)	3.3 (0.9, 10.8)	0
Unknown	47.9 (43.0, 52.8)	33.0 (27.5, 39.1)	45.9 (37.3, 54.7)	29.4 (20.0, 41.0)	20.3 (13.1, 30.2)
Duration of use, average months/year	5.7 (4.7, 6.7)	7.4 (6.0, 8.9)	5.6 (3.3, 8.5)	8.6 (6.0, 11.2)	8.0 (6.2, 9.9)
Unknown	12.2 (9.5, 15.6)	7.1 (4.9, 10.4)	11.6 (6.9, 18.8)	5.4 (2.5, 11.2)	3.3 (1.0, 10.8)
Ever daily use ^f	33.1 (29.1, 37.3)	45.9 (40.9, 51.0)	9.3 (6.2, 13.8)	40.3 (31.6, 49.7)	100.0

^aNumbers may not sum to 100% due to rounding; Past-year users exclude those who reported e-cigarette use in the past 30 days.

^bTwo users were dropped from these estimates because they were outliers (i.e., 20 and 35 years of e-cigarette use).

^cTwo past 30-day users reported their age of first use was 14 years old.

^dAll past 30-day users had 87.9% complete data. Quantity is shown for e-cigarette users reporting > 0 cartridges (n=364).

^eQuantity is shown for e-cigarette users reporting > 0 drops of e-liquid (n=94).

^fOne person in the past-year users and one person in the infrequent use group did not know if they were ever a daily user.

Table 4.

Correlation between e-cigarette use measures in United States adults, 2012–2013 National Epidemiologic Survey on Alcohol and Related Conditions-III.

Use Status	All e-cigarette users: cartridge, e-liquid, both				E-cigarette users: any e-liquid use			
	Cartridge quantity	E-liquid quantity	Nicotine concentration	Duration	Cartridge quantity	E-liquid quantity	Nicotine concentration	Duration
Past-year users ^a								
Cartridge quantity	1.00				1.00			
E-liquid quantity	-0.03	1.00			-0.04	1.00		
Nicotine concentration	-0.03	-0.07	1.00		0.00	-0.14	1.00	
Duration	0.01	0.00	-0.09	1.00	0.04	0.01	-0.08	1.00
All past 30-day users								
Cartridge quantity	1.00				1.00			
E-liquid quantity	0.28	1.00			0.40	1.00		
Nicotine concentration	-0.06	-0.12	1.00		0.06	-0.16	1.00	
Duration	0.05	0.08	-0.10	1.00	0.17	0.22	-0.16	1.00
Infrequent								
Cartridge quantity	1.00				1.00			
E-liquid quantity	-0.11	1.00			0.06	1.00		
Nicotine concentration	-0.10	-0.17	1.00		-0.39	-0.24	1.00	
Duration	0.04	-0.04	-0.06	1.00	0.35	-0.06	-0.18	1.00
Non-Daily								
Cartridge quantity	1.00				1.00			
E-liquid quantity	0.10	1.00			0.26	1.00		
Nicotine concentration	-0.07	-0.11	1.00		0.11	-0.15	1.00	
Duration	-0.11	-0.02	-0.19	1.00	-0.27	-0.04	-0.26	1.00
Daily								
Cartridge quantity	1.00				1.00			
E-liquid quantity	0.26	1.00			0.40	1.00		
Nicotine concentration	-0.03	-0.09	1.00		0.09	-0.19	1.00	
Duration	0.12	0.22	-0.06	1.00	0.21	0.31	-0.05	1.00

^aPast-year users exclude those who reported e-cigarette use in the past 30 days.