



Short communication

Heterogeneity in sociodemographic characteristics of people who use different ENDS devices

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ABSTRACT

Background: The electronic nicotine delivery systems (ENDS) market is heterogeneous with a wide variety of devices and liquids available to consumers. People with distinct sociodemographic characteristics may have different ENDS device and liquid preferences.

Methods: 1290 U.S. adults (21 +) using ENDS 5 + days/week completed the Wave 5 (February–April 2023) VAPER study survey and submitted photos of their most used ENDS device and liquid. Latent class analysis (LCA) was performed based on sociodemographic characteristics and cigarette smoking status to identify groups among respondents. We examined the association between identified groups and the device (disposable device/disposable pod/refillable pod/tank, power/airflow/coil modifiability)/liquid (nicotine salt/freebase) groupings found by exploratory factor analysis.

Results: Among our sample, there were three groups of adults frequently using ENDS: (1) group of women who are older, heterosexual, and have smoked cigarettes (62 % of the sample); (2) group of men who are higher-income and heterosexual (23 % of the sample); and (3) group of women who are younger and LGBTQ+ (16 % of the sample). The third group was more likely to use non-adjustable disposable devices with a nicotine salt liquid and less likely to use adjustable tanks with a freebase liquid than the other two groups ($p < 0.001$).

Conclusions: We found three distinct groups of adults frequently using ENDS. The group of younger LGBTQ+ women was different from the other two groups in use of device and liquid characteristics. Our findings can enhance understanding of people using ENDS and inform the expected impacts of ENDS regulatory efforts to protect public health.

1. Introduction

In 2021, 4.5 % of adults in the U.S. currently use electronic nicotine delivery systems (ENDS) (QuickStats, 2021). The ENDS market is changing rapidly and is highly heterogeneous with a wide variety of devices and liquids available to consumers (Cohen et al., 2022; O'Connor et al., 2022). Examining ENDS device and liquid together can provide a more comprehensive understanding of the chosen and used products. The most prevalent combination reported by more than one-third (36.2 %) of adults frequently using ENDS in 2020 was tank devices with adjustable settings and a freebase nicotine liquid, followed by disposable pods with non-adjustable settings and a nicotine salt liquid (22.8 %), refillable pods with adjustable settings and a nicotine salt

liquid (12.6 %), refillable pods with adjustable settings and a freebase liquid (8.1 %), and disposable devices with non-adjustable settings and a nicotine salt liquid (7.1 %) (Cohen et al., 2022). Since the U.S. Food and Drug Administration (FDA) issued a policy prioritizing enforcement against all flavors except menthol and tobacco from disposable pods such as JUUL in 2020 (U.S. FDA, 2020), there has been a decline in the use of disposable pods and a continuous increase in the use of disposable devices such as Elf Bar through the beginning of 2023 (Nian et al., 2023; CDC Foundation, 2023).

There are a handful of studies, with mixed findings, exploring the sociodemographic characteristics of adults using different ENDS devices and liquids characteristics, but they examined device and liquid characteristics separately. Based on Wave 3 (2015–2016) of the Population

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Assessment of Tobacco and Health (PATH) Study data, people using refillable ENDS were more likely to be younger (Sharma et al., 2021; Coleman et al., 2019), male, non-Hispanic White, formerly smoked, and use ENDS daily (Coleman et al., 2019); and people using disposable ENDS were less likely to be White compared to people using other device types (Sharma et al., 2021). A study of vape store customers in California in July 2019–March 2020 found that people using disposable pods were younger and used higher nicotine concentration levels, while less likely to ever use cigarettes and use ENDS daily compared to people using refillable pods and other non-pod ENDS (Galimov et al., 2021).

Little is known about the sociodemographic characteristics of adults using different combinations of ENDS device types, device adjustability and liquid formulations, with the most recent data to reflect the rapidly changing ENDS market. To fill this gap, we used data in 2023 to examine the common sociodemographic traits among adults using ENDS and the groupings of device and liquid they utilize to inform ENDS regulatory efforts as well as interventions for people with specific attributes.

2. Methods

This study used wave 5 (February–April 2023) data ($n = 1290$) of the Vaping and Patterns of E-cigarette Use Research (VAPER) study, a longitudinal cohort study among U.S. adults (age 21 +) using ENDS at least 5 days/week. Details about the VAPER Study methodology have been reported (Hardesty et al., 2023). Adults were recruited to participate in an online survey hosted by REDCap and were asked to report their ENDS use behaviors. A range of security, data integrity and data quality strategies were employed. Respondents were also asked about their most used device including questions about device characteristics such as reusability, refillability, use of a tank or pod, and modifiability of the power or airflow or coil; and about liquid characteristics such as nicotine formulation. In addition to answering survey questions, respondents submitted photos of their most used device and liquid. The Virginia Commonwealth University Institutional Review Board (IRB) approved the study (HM20015004), with the Johns Hopkins Bloomberg School of Public Health IRB relying on the VCU IRB as the IRB of record (IRB9277).

Latent class analysis (LCA) is a probabilistic modelling algorithm that can be used to group participants from multivariate data into subgroups with similar, unobservable memberships. By using the R 4.2.1 package “poLCA” (Linzer and Lewis, 2011), we found latent groups within our sample of U.S. adults using ENDS that shared certain characteristics based on the pattern of their responses to a series of indicators, including sociodemographic characteristics (gender [woman, man], age [<30 , $30 +$], race [single race White, single race non-White or mixed race], annual household income [$< \$40,000$, $\$40,000 +$], and sexual orientation [heterosexual, non-heterosexual]); and cigarette smoking status (never smoked, others). We undertook LCA using maximum likelihood estimates.

Exploratory factor analysis (EFA), a statistical technique which can reduce data to a smaller set of summary variables (i.e., factors), was conducted to identify the underlying relationships between ENDS device and liquid characteristics. Principal axis factoring analysis was used as the extraction method due to the assumption of latent constructs. Direct oblimin was chosen as the rotation method because significant correlations were found among variables. Internal consistency of the variables within factors was tested by Cronbach’s alpha (Tavakol and Dennick, 2011).

Chi-square tests were used to test the differences between various groups (determined by LCA) in using device/liquid groupings (determined by EFA). A 2-sided $p < 0.05$ was considered statistically significant.

3. Results

The majority of respondents were White (75.7 %), non-Hispanic

(88.3 %) and heterosexual (69.5 %); about half (48.5 %) had an annual income less than \$40,000; 29.3 % of respondents were less than 30 years old and 22.7 % first used ENDS before 21 years old (Appendix 1).

We created five LCA models with 2 to 6 latent classes. The optimal number of classes was determined based on the statistical fit measures (Akaike Information Criteria [AIC], Bayesian Information Criteria [BIC] and log likelihood), model parsimony and interpretability (Nylund et al., 2007; Sinha et al., 2021). The 3-class model fit the data best, as it optimally minimized AIC and BIC while providing relatively fewer but meaningful groups (Appendix 2). Three groups identified by LCA were interpreted as: (1) women (prob = 0.75) who are older (age 30+; prob = 0.88), heterosexual (prob = 0.77), and have smoked cigarettes (prob = 0.94) (62 % of the sample); (2) men (prob = 0.75) who are higher-income (annual income \$40,000+; prob = 0.83) and heterosexual (prob = 0.94) (23 % of the sample); and (3) women (prob = 0.84) who are younger (under age 30; prob = 0.90) and LGBTQ+ (prob = 0.70) (16 % of the sample) (Table 1).

The EFA showed that device type, adjustable settings, and nicotine formulation exhibited factorability, all loading onto one factor (Appendix 3). We then created a device/liquid grouping variable based on this underlying factor. Above 90 % of respondents reported using one of the five device/liquid groupings: (1) disposable device with non-adjustable settings and a nicotine salt liquid (37.1 %) such as Elf Bar BC5000; (2) tank device with adjustable settings and a freebase liquid (20.3 %) such as GeekVape Aegis L200 with a freebase liquid; (3) disposable pod device with nonadjustable settings and a nicotine salt liquid (12.2 %) such as JUUL; (4) refillable pod device with adjustable settings and a nicotine salt liquid (11.6 %) such as SMOK Novo 4 with a nicotine salt liquid; and (5) refillable pod device with adjustable settings and a freebase liquid (10.5 %) such as SMOK Novo 5 with a freebase liquid.

Using the three groups determined by the LCA, we examined the preference for device/liquid grouping (Table 2). The top device/liquid grouping choice of all three groups was a non-adjustable disposable device with a nicotine salt liquid. More than half of respondents (54.2 %) in the group of women who are younger and LGBTQ + used this device/liquid grouping which was significantly higher than the other two groups (group of women who are older, heterosexual and have smoked cigarettes: 33.6 %; group of men who are higher-income and heterosexual: 32.8 %; $p < 0.001$). Above 20 % of respondents in the group of women who are older, heterosexual and have smoked cigarettes (21.9 %) and the group of men who are higher-income and heterosexual (23.5 %) used adjustable tanks with a freebase liquid, which was significantly higher than the group of women who are younger and LGBTQ+ (7.9 %, $p < 0.001$). And 11.5 % of respondents in the group of women who are older, heterosexual and have smoked cigarettes used adjustable refillable pods with a freebase liquid which was significantly higher than the group of women who are younger and LGBTQ+ (5.9 %, $p < 0.05$). The group of women who are older, heterosexual and have smoked cigarettes and the group of men who are higher-income and heterosexual had no significant difference in the preference for device/liquid grouping.

4. Discussion

A comprehensive understanding of device and liquid preferences among people using ENDS can help inform ENDS regulatory efforts aimed at protecting public health. Using LCA, we were able to identify three distinct groups of U.S. adults who used ENDS frequently – a group of women who are older, heterosexual and have smoked cigarettes, a group of men who are higher-income and heterosexual, and a group of women who are younger and LGBTQ +. Differences in device/liquid grouping preferences were observed between the group of younger and LGBTQ + women and the other two groups.

This study provides some evidence to inform regulations of ENDS

Table 1
Probability of attributes by group identified by LCA, VAPER study, Wave 5, United States, 2023.

		Group 1: women who are older, heterosexual and have smoked cigarettes	Group 2: men who are higher-income and heterosexual	Group 3: women who are younger and LGBTQ+	Total
Gender	Total proportion	61.6	22.7	15.7	100
	n (total N = 1290)	794	293	203	1290
	Man	0.25	1.00	0.16	0.39
	Woman	0.75	0.00	0.84	0.61
Age	Below 30	0.12	0.33	0.90	0.29
	30+	0.88	0.67	0.10	0.71
Race	Single race White	0.82	0.69	0.66	0.76
	Single race non-White/ multi-race	0.18	0.31	0.34	0.24
Annual Income	Below \$40 K	0.58	0.17	0.59	0.49
	\$40 K+	0.42	0.83	0.41	0.51
Sex Orientation	Heterosexual	0.77	0.94	0.38	0.70
	non-Heterosexual	0.23	0.06	0.62	0.30
Cigarette smoking Status	Never smoker	0.06	0.16	0.39	0.13
	Others	0.94	0.84	0.61	0.87

Table 2
Distribution of each device/liquid grouping across the three groups identified by LCA, VAPER study, Wave 5, United States, 2023.

Device/Liquid Grouping	Group 1: women who are older, heterosexual and have smoked cigarettesn (%)	Group 2: men who are higher-income and heterosexualn (%)	Group 3: women who are younger and LGBTQ + n (%)
Disposable device (salt, no adj settings)	267 (33.6)	96 (32.8)	110 (54.2)*
Refillable tank (freebase, adj settings)	174 (21.9)	69 (23.5)	16 (7.9)*
Disposable pod (salt, no adj settings)	100 (12.6)	31 (10.6)	25 (12.3)
Refillable pod (salt, adj settings)	80 (10.1)	42 (14.3)	26 (12.8)
Refillable pod (freebase, adj settings)	91 (11.5)	31 (10.6)	12 (5.9)**
Others	82 (10.3)	24 (8.2)	14 (6.9)

Note. *Group 3 vs Group 1 & 2, $p < 0.001$. ** Group 1 vs Group 3, $p < 0.05$.

device and liquid characteristics and interventions for people with specific attributes. We found that, in 2023, the group of women who are younger and LGBTQ + was more likely to use non-adjustable disposable devices with a nicotine salt liquid such as Elf Bar, however, a study in 2020 found that people aged 13-24 who identified as LGBTQ + were more likely to use disposable pods (Gaiha et al., 2022). The inconsistent findings may be attributed to the rapidly changing ENDS market. Before the FDA flavor decision in 2020, which only bans flavored disposable pods (other than tobacco- or menthol-flavored) and excludes flavored disposable devices and liquids used in tanks or refillable pods (Hemmerich, 2020), disposable pods like JUUL were the most used type of ENDS among adolescents (Majmundar et al., 2022; Sidani et al., 2019). Since 2020, there has been a decline in the sales of disposable pods, while the market for disposable devices, such as Elf Bar, has experienced continuous growth (CDC Foundation, 2023). In 2021, the use of disposable devices surpassed that of disposable pods as the preferred type of ENDS among adolescents. We also observed the prevalence of non-adjustable disposable devices with a nicotine salt liquid among adults. It is the most popular device/liquid grouping across groups, with above half of the group of women who are younger and LGBTQ + reporting using this grouping in 2023.

Adjustable tank with a freebase liquid was the second most prevalent

device/liquid grouping in 2023. The group of women who are older, heterosexual and have smoked cigarettes and the group of men who are higher-income and heterosexual were more likely to use this device/liquid grouping compared to the group of women who are younger and LGBTQ +. Previous studies suggested that males and people who formerly smoked were more likely to use refillable ENDS (Coleman et al., 2019).

Device type or characteristic-specific regulations could disproportionately impact groups with distinct sociodemographic characteristics and cigarette smoking histories, although additional study is required. For example, higher excise taxes on disposable devices or banning the use of nicotine salts could lead to disproportionate behavior changes for women who are younger and LGBTQ+: they may transition at higher rates to using ENDS with a freebase liquid, stop using ENDS, or start smoking cigarettes. In addition, the findings of this study could inform education campaigns and smoking cessation programs that target specific populations to improve health equity.

The strengths of this study include the use of person-centered approach (i.e., LCA) that concurrently examines the sociodemographic characteristics of U.S. adults frequently using ENDS and explores the association between groups obtained by LCA and their ENDS device/liquid grouping preference using recent survey data. One limitation is that we reported respondents' most commonly used device and liquid; however, respondents may use additional device(s) and/or liquid(s). Additionally, although LCA is a rigorous statistical method, the class assignments are not guaranteed to be completed accurately and the class membership is complex (Weller et al., 2020). Because of the complexity of class membership, we were not able to assign simple names that were sufficiently descriptive of each group.

5. Conclusions

Three groups of U.S. adults frequently using ENDS were identified, each with distinct sociodemographic characteristics and cigarette smoking status. The group of women who are younger and LGBTQ + is more likely to use non-adjustable disposable devices with a nicotine salt liquid and less likely to use adjustable tanks with a freebase liquid than the other two groups. The findings of this study can enhance understanding of people using ENDS frequently and inform projected impacts of regulatory efforts on ENDS to ensure the protection of public health.

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CRedit authorship contribution statement

Qinghua Nian: . **Joanna E. Cohen:** . **Joshua Sinamo:** Data curation, Formal analysis, Methodology, Writing – review & editing, Software. **Elizabeth Crespi:** Data curation, Project administration, Writing – review & editing. **Raniyan Zaman:** Resources, Writing – review & editing. **Jeffrey J. Hardesty:** Conceptualization, Project administration, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.pmedr.2023.102561>.

References

- Cohen, J.E., Hardesty, J.J., Nian, Q., et al., 2022. Combinations of electronic nicotine delivery system device and liquid characteristics among U.S. adults. *Addict. Behav.* 135, 107441. <https://doi.org/10.1016/j.addbeh.2022.107441>.
- Coleman, B., Chang, J.T., Rostron, B.L., Johnson, S.E., Das, B., Del Valle-Pinero, A.Y., 2019. An examination of device types and features used by adult electronic nicotine delivery system (ENDS) users in the PATH Study, 2015–2016. *Int. J. Environ. Res. Public Health* 16 (13), 2329. <https://doi.org/10.3390/ijerph16132329>.
- U.S. Food and Drug Administration. Enforcement priorities for electronic nicotine delivery systems (ENDS) and other deemed products on the market without premarket authorization (Revised). <https://www.fda.gov/media/133880/download>. Accessed 19 August 2023.
- CDC Foundation. Monitoring U.S. e-cigarette sales: national trends. March 2023. <https://www.cdcfoundation.org/National-E-CigaretteSales-DataBrief-2023-Mar26?inline>. Accessed 19 May 2023.
- Gaiha, S.M., Rao, P., Halpern-Felsher, B., 2022. Sociodemographic factors associated with adolescents' and young adults' susceptibility, use, and intended future use of different e-cigarette devices. *Int. J. Environ. Res. Public Health* 19 (4), 1941. <https://doi.org/10.3390/ijerph19041941>.
- Galimov, A., Leventhal, A., Meza, L., et al., 2021. Prevalence of disposable pod use and consumer preference for e-cigarette product characteristics among vape shop customers in Southern California: a cross-sectional study. *BMJ Open* 11 (10), e049604.
- Hardesty, J.J., Crespi, E., Nian, Q., et al., 2023. The vaping and patterns of e-cigarette use research study: protocol for a web-based cohort study. *JMIR Res Protoc.* 12, e38732.
- Hemmerich, N., 2020. Flavoured pod attachments score big as FDA fails to enforce premarket review. *Tob. Control* 29 (e1), e129.
- Linzer, D.A., Lewis, J.B., 2011. PoLCA: An R package for polytomous variable latent class analysis. *J Stat Soft.* 42 (10), 1–29. <https://doi.org/10.18637/jss.v042.i10>.
- Majmundar, A., Xue, Z., Asare, S., Nargis, N., 2022. Trends in public interest in shopping and point-of-sales of JUUL and Puff Bar 2019–2021. *Tob. Control.* <https://doi.org/10.1136/tobaccocontrol-2021-056953> tobaccocontrol-2021-056953.
- Nian, Q., Hardesty, J.J., Crespi, E., et al., 2023. Transitions in device and liquid characteristic groupings among U.S. adults frequently using electronic nicotine delivery systems over three timepoints, 2020–2021. *Tob. Induc. Dis.* 21, 134. <https://doi.org/10.18332/tid/171354>.
- Nylund, K.L., Asparouhov, T., Muthén, B.O., 2007. Deciding on the number of classes in latent class analysis and growth mixture modeling: a Monte Carlo simulation study. *Struct. Equ. Model.* 14, 535–569. <https://doi.org/10.1080/10705510701575396>.
- O'Connor, R., Schneller, L.M., Felicione, N.J., Talhout, R., Goniewicz, M.L., Ashley, D.L., 2022 Mar. Evolution of tobacco products: Recent history and future directions. *Tob. Control* 31 (2), 175–182. <https://doi.org/10.1136/tobaccocontrol-2021-056544>.
- QuickStats: Percentage distribution of cigarette smoking status among current adult e-cigarette users, by age group — National Health Interview Survey, United States, 2021. *MMWR Morb Mortal Wkly Rep.* 2023;72:270. doi: 10.15585/mmwr.mm7210a7.
- Sharma, E., Yang, D.H., Stroud, L.R., 2021. Variations in electronic nicotine delivery system (ENDS) device types and association with cigarette quit attempts. *Prev. Med.* 148, 106588 <https://doi.org/10.1016/j.ypmed.2021.106588>.
- Sidani, J.E., Colditz, J.B., Barrett, E.L., et al., 2019. I wake up and hit the JUUL: analyzing Twitter for JUUL nicotine effects and dependence. *Drug Alcohol Depend.* 204, 107500 <https://doi.org/10.1016/j.drugalcdep.2019.06.005>.
- Sinha, P., Calfee, C.S., Delucchi, K.L., 2021. Practitioner's guide to latent class analysis: Methodological considerations and common pitfalls. *Crit. Care Med.* 49 (1), e63–e79. <https://doi.org/10.1097/CCM.00000000000004710>.
- Tavakol, M., Dennick, R., 2011. Making sense of Cronbach's alpha. *Int. J. Med. Educ.* 2, 53–55. <https://doi.org/10.5116/ijme.4dfb.8dfd>.
- Weller, B.E., Bowen, N.K., Faubert, S.J., 2020. Latent class analysis: A guide to best practice. *J. Black Psychol.* 46 (4), 287–311. <https://doi.org/10.1177/0095798420930932>.