



## Changing patterns in E-cigarette use among Minnesota adults between 2014 and 2018

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### ABSTRACT

Minnesota has observed declining combustible tobacco use and a large increase in e-cigarette use among youth and young adults. Less is known about adult e-cigarette users' frequency of use, smoking status, use of flavors, and demographic differences. The Minnesota Adult Tobacco Survey (MATS) is a cross-sectional, random digital telephone survey representative of Minnesotans aged 18 and over. MATS measured e-cigarette use in 2014 (N = 9304) and 2018 (N = 6065). In 2018, 6.0% of adult Minnesotans used an e-cigarette in the past 30 days; this was unchanged from 2014 (5.9%). While past 30-day e-cigarette use declined for current smokers (2014: 27.3%; 2018: 16.1%  $p < 0.001$ ), it increased for never smokers (2014: 1.2%; 2018: 4.4%  $p < 0.001$ ) and 18–24-year-olds (2014: 12.8%; 2018: 21.9%  $p = 0.001$ ). Daily e-cigarette use increased from 2014 to 2018 for current smokers ( $p = 0.001$ ), 25–44-year-olds ( $p < 0.001$ ), females ( $p = 0.001$ ), and those with a high-school education ( $p = 0.006$ ). Among e-cigarette users in 2018, use of flavored e-cigarettes was associated with smoking status ( $p = 0.041$ ), age ( $p < 0.001$ ), and using e-cigarettes to quit smoking ( $p = 0.011$ ). E-cigarettes appeal primarily to younger adults. Of concern are increases in never smokers initiating e-cigarette use, increasing their exposure to nicotine, addiction, and the risk of future combustible tobacco use. Simultaneously, fewer smokers are using e-cigarettes but those who do are using them more frequently. Use of flavored e-cigarettes was common and correlated with interest in quitting combustible cigarettes. These findings can inform recent calls for additional tobacco control policy and programs aimed at reducing e-cigarette use.

### 1. Introduction

Electronic cigarettes (e-cigarettes) are the most widely used tobacco product among those ages 12–18 in the United States surpassing the use of combustible cigarettes nationally in 2014 (Gentzke et al., 2019; Arrazola et al., 2015). Their use among all adults (18 and older) remains low, decreasing from 3.7% in 2014 to 2.8% in 2017 (Bao et al., 2018; Wang et al., 2018). Evidence is evolving about the health effects and whether there is a net population benefit of e-cigarettes to assist smokers in quitting combustible tobacco use (Ghosh and Drummond, 2017; National Academies of Sciences E Medicine, 2018).

The National Academies of Sciences, Engineering, and Medicine's 2018 report on the public health consequences of e-cigarettes found

conclusive evidence that e-cigarette use increases exposure to highly variable nicotine levels and potentially toxic substances. While long-term health effects of e-cigarettes are unknown, the report notes that completely substituting e-cigarettes for combustible cigarettes reduces exposure to numerous toxicants (National Academies of Sciences E Medicine, 2018). However, there is also substantial evidence that e-cigarette use increases the risk of ever using combustible cigarettes in youth and young adults (National Academies of Sciences E Medicine, 2018; Berry et al., 2019; Primack et al., 2018; Leventhal et al., 2015).

E-cigarettes became widely available in 2006 with the introduction of cigarette-like devices into the market. However, these early generation devices did not deliver nicotine effectively due to low battery power capacity (National Academies of Sciences E Medicine, 2018;

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Hajek et al., 2017; Margham et al., 2016). There was a significant shift in the Electronic Nicotine Delivery Systems (ENDS; which includes e-cigarettes, vaporizers, hookah pens and the like) market from 2014 to 2015 with the introduction of sleek, USB-like, higher nicotine content e-cigarette devices. Many of these new devices are pod-based, and are sold in a variety of flavor options (McKelvey et al., 2018). In the years following this ENDS market shift, there was a significant increase in the use of e-cigarettes by young people, with national studies indicating that e-cigarette use is most prevalent among high school-aged youth (Gentzke et al., 2019). In addition, many youth and young adults report that the availability of fruit and candy flavors is part of the appeal of e-cigarettes (Tsai et al., 2018).

Less is known about the changing profile of adult e-cigarette users from their introduction until now, especially as it relates to frequency of use, smoking status, and use of flavors. Studies that have followed e-cigarette users over time have found that most were using both combustibles and vaping products instead of completely switching to e-cigarettes (National Academies of Sciences E Medicine, 2018; Weaver et al., 2018). Many adults report cessation as a reason for using e-cigarettes, (QuickStats, 2016), but to date, there remains limited and conflicting evidence on the effectiveness of e-cigarettes to support quitting (Ghosh and Drummond, 2017; Borrelli and O'Connor, 2019; Patel et al., 2016). In contrast, a recent study among young adults found that few use e-cigarettes to help them reduce smoking, and their use of e-cigarettes is associated with more frequent and intensive cigarette smoking, not less (Olfson et al., 2019). Unlike youth, preferring more e-cigarette flavors is not associated with e-cigarette use frequency among adults (Morean et al., 2018).

As policymakers continue to assess the impact that e-cigarettes have on overall tobacco use trends, it is important to accurately assess and understand the changing use patterns of these products. This study provides a cross-sectional examination of Minnesota adult e-cigarette use in 2014, when the sale of the current generation of USB e-cigarette devices greatly increased, through 2018. These data will add to the understanding of the changing landscape of e-cigarette use among a representative state-level adult population to inform future policy, prevention and treatment efforts.

## 2. Methods

### 2.1. Survey/data sources

Minnesota Adult Tobacco Survey (MATS) 2014 and 2018 data were used for this study. MATS used computer-assisted telephone interviewing and a random digit dialing (RDD) methodology to obtain a cross-sectional sample of civilian, non-institutionalized adults aged 18 years or older living in Minnesota. MATS 2014 and 2018 used dual-frame landline and cell phone RDD sampling. The survey was administered after initial screening questions identified eligible households and individuals. The same calling protocol was used in both survey years with call attempts made to convert refusers. Letters were mailed to refusers and non-responders with valid addresses encouraging them to call a toll free number to complete the survey.

The study team acquired approval from the Minnesota Department of Health Institutional Review Board. The MATS 2014 final sample included 9304 respondents and standard American Association for Public Opinion Research (AAPOR) response rates of 25.2% for landline and 18.2% for cell phone frames. The final sample for MATS 2018 was 6055 with AAPOR response rates of 17.5% for landline and 13.4% for cell phone. Weighting was conducted to create unbiased population estimates based on the probability of selection due to the sampling plan. Additionally, weights were calibrated based on sex, race, location, and education totals from the US Census Bureau's American Community Survey. More methodological detail is available at <http://www.clearwaymn.org/MATS>.

### 2.2. Measures

Instrument items were identical in MATS 2014 and 2018 unless otherwise noted.

Past 30-day e-cigarette use: Participants who reported using an electronic cigarette at least once in their lives were asked, "During the past 30 days, on how many days did you use e-cigarettes?" Those who responded between 1 and 30 days were categorized as past 30-day e-cigarette users.

Frequency of e-cigarette use: The frequency of e-cigarette use in the past 30 days was categorized into three groups: Infrequent (1–5 days), Intermediate (6–29 days), and Daily (30 days), based on findings from Amato et al. (2016) using MATS 2014 data, and confirmed by the distributions in the MATS 2018 data.

Use of e-cigarettes to quit: Respondents who ever used an e-cigarette were asked the yes/no item, "The last time you tried to quit smoking, did you use e-cigarettes to help you quit?"

Cigarette smoking: Smoking status (current smoker, former smoker, or never smoker) was defined using the Behavioral Risk Factor Surveillance System (BRFSS) methodology (Behavioral Risk Factor Surveillance System, 2017).

Flavored e-cigarette use: In MATS 2018, flavored past 30-day e-cigarette use was measured with the yes/no item, "Is your usual e-cigarette or e-juice flavored to taste like menthol, mint, clove, spice, fruit, chocolate, alcoholic drinks, candy or other sweets?" Due to wording changes, the similar question on MATS 2014 is not comparable to 2018.

### 2.3. Analysis

Statistical analyses were performed with SAS version 9.4. Chi-square tests were conducted using PROC SURVEYFREQ and were used to determine statistical significance in pairwise and stratified analyses with p-value criteria of 0.05. P-value criteria were adjusted for multiple comparisons (tables larger than  $2 \times 2$ ) using Bonferroni correction. Cells that included unweighted sample sizes of less than 10 are not reported.

## 3. Results

### 3.1. Past 30-day e-cigarette use in 2018

In 2018, past 30-day e-cigarette use was associated with smoking status, age, gender, education, and income ( $p \leq 0.012$ ). See Table 1. Current smokers (16.1%) were more likely to use e-cigarettes than both former smokers (4.4%,  $p < 0.001$ ) and never smokers (4.4%,  $p < 0.001$ ). Young adults (18–24 years) were three times more likely to use e-cigarettes (21.9%) than older adults; all differences between age groups were statistically significant and showed lower use with older age ( $p < 0.001$ ). Men (8.0%) were more likely than women (4.1%,  $p < 0.001$ ) to use e-cigarettes. Those with less than a high-school education (14.1%) were more likely to use e-cigarettes than high-school graduates (6.5%,  $p < 0.001$ ) and those with a college degree (2.2%,  $p < 0.001$ ). Despite an overall association with income and e-cigarette use, there were no statistically significant differences between income groups.

### 3.2. Changes in past 30-day e-cigarette use from 2014 to 2018

Past 30-day e-cigarette use declined for current smokers from 27.3% in 2014 to 16.1% in 2018 ( $p < 0.001$ ). Conversely, e-cigarette use increased for never smokers from 1.2% in 2014 to 4.4% in 2018 ( $p < 0.001$ ). E-cigarette use also increased among 18–24-year-olds from 12.8% in 2014 to 21.9% in 2018 ( $p = 0.001$ ). See Table 1. No significant changes were seen from 2014 to 2018 within gender, education, or income categories. Changes in flavored e-cigarette use from 2014 to 2018 were not assessed due to a difference in question-wording

**Table 1**  
Past 30-day e-cigarette use in 2014 and 2018.

	MATS 2014		MATS 2018			
	N*	Past 30-day e-cigarette use %	No past 30-day e-cigarette use %	N*	Past 30-day e-cigarette use %	No past 30-day e-cigarette use %
<i>Smoking status</i>						
Current smoker†	1154	27.3	72.7	645	16.1	83.9
Former smoker	2856	4.8	95.2	1791	4.4	95.6
Never smoker†	5216	1.2	98.8	3555	4.4	95.6
<i>Age</i>						
18–24†	682	12.8	87.2	437	21.9	78.1
25–44	2291	7.8	92.2	1396	6.8	93.2
45–64	3496	4.3	95.7	2094	2.8	97.2
65 and older	2829	0.8	99.2	2121	0.5	99.5
<i>Gender</i>						
Male	4146	7.0	93.0	2781	8.0	92.0
Female	5151	4.9	95.1	3267	4.1	95.9
<i>Education</i>						
Less than high school	409	9.6	90.4	203	14.1	85.9
High-school graduate/GED	2241	7.1	92.9	1287	6.5	93.5
Some college or technical school	3108	7.3	92.7	1955	7.3	92.7
College graduate or beyond	3492	2.5	97.5	2566	2.2	97.8
<i>Income</i>						
Less than \$10,000	417	6.4	93.6	197	9.0	91.0
\$10,001–\$20,000	693	11.9	88.1	361	8.5	91.5
\$20,001–\$25,000	505	6.1	93.9	258	7.9	92.1
\$25,001–\$35,000	765	6.0	94.0	451	8.3	91.7
\$35,001–\$50,000	1169	8.4	91.6	649	8.0	92.0
\$50,001–\$75,000	1585	6.2	93.8	951	4.6	95.4
More than \$75,000	2999	4.2	95.8	2409	4.3	95.7

\*Ns in this table are the unweighted number of survey respondents, though all percentages are weighted.

†Change from 2014 to 2018 within this group is statistically significant at  $p \leq 0.05$ .

on the two surveys.

### 3.3. Past 30-day flavored e-cigarette use in 2018

Among e-cigarette users in 2018, the use of flavored e-cigarettes was associated with smoking status ( $p = 0.041$ ), age ( $p < 0.001$ ), and using e-cigarettes to quit smoking ( $p = 0.011$ ). See Table 2. Never smokers (87.1%) were more likely than former smokers (66.0%,  $p = 0.009$ ) to use flavored e-cigarettes; current smokers (77.8%) were not statistically different than former or never smokers in the use of flavors. Young adults (18–24 years) were more likely to use flavored e-cigarettes (96.5%) compared to older adults ( $p \leq 0.002$ ). Those who reported using e-cigarettes to quit smoking (82.8%) were more likely to use flavored e-cigarettes than those who did not (55.5%,  $p = 0.011$ ). No differences in flavored e-cigarette use existed based on gender, education, income, or frequency of e-cigarette use ( $p \geq 0.081$ ).

### 3.4. Changes in e-cigarette frequency of use from 2014 to 2018

Daily e-cigarette use increased from 2014 to 2018 for current smokers ( $p = 0.001$ ), 25 to 44-year-olds ( $p < 0.001$ ), females ( $p = 0.001$ ), and those with a high-school education ( $p = 0.006$ ). A lower percentage of young adult (18–24 years) e-cigarette users were infrequent users in 2018 (49.4%) than in 2014 (72.8%,  $p = 0.008$ ). See Table 3 and Fig. 1. While the overall association between e-cigarette frequency and survey year was significant for never smokers, cell sizes

**Table 2**  
Use of flavored e-cigarettes among past 30-day e-cigarette users in 2018.

	N*	Usual e-cigarette or e-juice is flavored		$\chi^2$	df	p value
		Yes %	No %			
<i>Smoking status</i>						
Current smoker	85	77.8	22.2	6.40	2	0.041
Former smoker	51	66.0	34.0			
Never smoker	92	87.1	12.9			
<i>Age</i>						
18–24	95	96.5	3.5	73.53	3	< 0.001
25–44	85	82.8	17.2			
45–64	42	35.7	64.3			
65 and older	10	20.9	79.1			
<i>Gender</i>						
Male	160	75.7	24.3	3.05	1	0.081
Female	72	87.4	12.6			
<i>Education</i>						
Less than high school	18	84.8	15.2	2.81	3	0.422
High-school graduate/GED	76	72.8	27.2			
Some college or technical school	90	83.5	16.5			
College graduate or beyond	47	71.8	28.2			
<i>Income</i>						
Less than \$10,000	17	77.2	22.8	4.33	6	0.632
\$10,001–\$20,000	20	85.3	14.7			
\$20,001–\$25,000	17	91.3	8.7			
\$25,001–\$35,000	22	78.1	21.9			
\$35,001–\$50,000	28	84.7	15.3			
\$50,001–\$75,000	29	78.1	21.9			
More than \$75,000	70	70.0	30.0			
Used e-cigarettes to help quit smoking						
Yes	69	82.8	17.2	6.48	1	0.011
No	34	55.5	44.5			
<i>E-cigarette frequency of use</i>						
Infrequent (1–5 days)	102	81.6	18.4	4.78	2	0.092
Intermediate (6–29 days)	56	88.2	11.8			
Daily (30 days)	74	71.6	28.4			

\*Ns in this table are the unweighted number of survey respondents, though all percentages are weighted.

were too small to report between-group differences.

## 4. Discussion

Patterns of e-cigarette use among Minnesota adults changed significantly during the study period of 2014–2018. While the overall prevalence of adult Minnesotans’ past 30-day e-cigarette use remained unchanged, there was an increase in the use of these devices among younger adults (18–24-year-olds) and never smokers, and a decline in use among current smokers. Similarly, daily use of e-cigarettes increased among women, current and never smokers, and infrequent use declined significantly among 18–24-year-olds. These shifts suggest that the product is less appealing to established smokers as a way to switch or quit combustibles. Instead, some – most notably young adults and never smokers – are using these novel products with greater frequency.

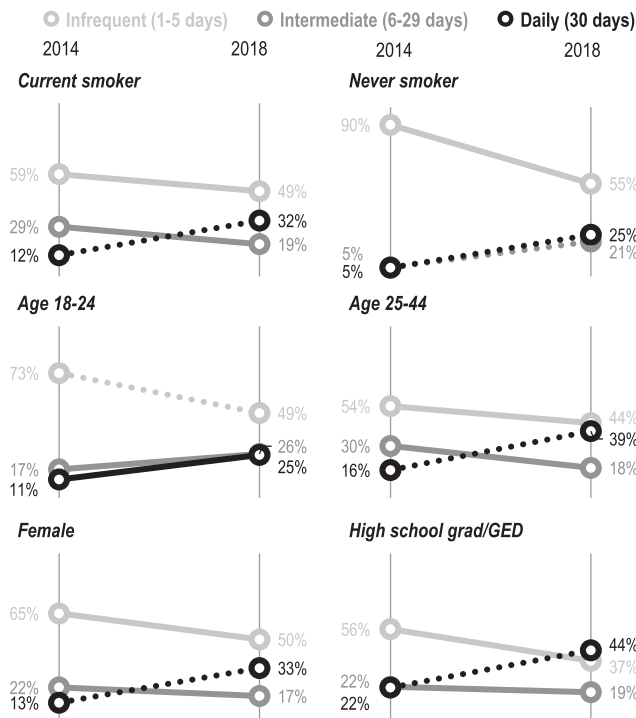
This study’s findings are consistent with national findings that show the prevalence of e-cigarette use is highest among young adults aged 18–24 compared to those 25 and older (Mirbolouk et al., 2018; Hu et al., 2019; Coleman et al., 2017). MATS data showed that women and younger adults are also using e-cigarettes more frequently in 2018 compared to 2014 indicating a growing appeal. Among 18–24 year olds, we found a significantly lower percentage are infrequent users (1–5 days in the past 30), and a larger percentage are using with increased frequency (6–29 and 30 days of the past 30) in 2018 than in 2014. These results are consistent with reports that youth and young adults are quickly becoming addicted to these products (Jackler and Ramamurthy, 2019).

**Table 3**  
Changes in the frequency of e-cigarette use among past 30-day e-cigarette users, 2014–2018.

	MATS 2014			MATS 2018				
	N*	Infrequent (1–5 days) %	Intermediate (6–29 days) %	Daily (30 days) %	N*	Infrequent (1–5 days) %	Intermediate (6–29 days) %	Daily (30 days) %
<i>Smoking status</i>								
Current smoker†	277	59.0	28.7	12.3	88	49.2	18.6	32.2
Former smoker	86	43.2	16.0	49.9	51	21.6	25.9	52.5
Never smoker†	49	89.5	5.4	5.1	94	54.8	20.6	24.6
<i>Age</i>								
18–24†	91	72.8	16.6	10.7	96	49.4	25.6	25.0
25–44†	159	53.5	30.3	16.2	88	43.6	17.5	38.9
45–64	138	55.8	16.5	27.7	43	43.5	17.0	39.5
65 and older	25	44.9	25.6	26.5	10	53.2	26.2	20.6
<i>Gender</i>								
Male	230	54.4	24.0	21.6	163	44.3	23.3	32.4
Female†	183	65.1	21.9	13.0	74	49.9	16.9	33.2
<i>Education</i>								
Less than high school	28	55.4	32.1	12.5	19	54.8	17.3	28.0
High-school graduate/GED†	132	55.9	22.3	21.8	78	37.4	19.1	43.6
Some college or technical school	174	57.2	25.1	17.7	91	45.9	24.5	29.6
College graduate or beyond	78	74.1	11.4	14.5	47	59.1	21.5	19.4

\*Ns in this table are the unweighted number of survey respondents, though all percentages are weighted.

†Change from 2014 to 2018 within this group is statistically significant at  $p \leq 0.05$ .



Dotted lines represent statistically significant between-group comparisons with Bonferroni adjustment ( $p \leq 0.017$ ).

**Fig. 1.** Changes in the frequency of e-cigarette use among past 30-day e-cigarette users, 2014–2018.

Overall, fewer current smokers are using e-cigarettes, while the use of e-cigarettes among never smokers (tobacco-naïve) dramatically increased between 2014 and 2018. These findings signal that many tobacco-naïve e-cigarette users may be starting their nicotine use with e-cigarettes. Further surveillance is needed to determine whether or not these users will progress to other forms of tobacco products beyond e-cigarettes, though there is evidence that this is already the case, especially among young people (National Academies of Sciences E Medicine, 2018; Pisinger, 2014; Berry et al., 2019; Sharapova et al.,

2018). Although this study did not examine age at first use of e-cigarettes, future studies should assess it to better understand the timing of initiation and trajectory of progression of use, either from adolescence or young adulthood and onwards.

While fewer smokers are using e-cigarettes, those who use both tobacco products are using e-cigarettes more intensely with significant increases in daily use (Pisinger, 2014). These findings are concerning as e-cigarettes only offer potential harm reduction benefits when smokers switch completely to e-cigarettes, and recent studies suggest that dual use is common and harmful (National Academies of Sciences E Medicine, 2018; QuickStats, 2016; Wang et al., 2018; Goniewicz et al., 2018; Rosen and Steinberg, 2019). Additional studies using qualitative, and longitudinal survey methods would be useful in understanding the decline in e-cigarette use among smokers and the factors smokers consider in not entirely switching to e-cigarettes.

We found that in 2018, the use of flavored e-cigarettes is common across demographic categories and is particularly high among never smokers and current smokers who reported using e-cigarettes in their last attempt to quit. Studies on youth demonstrate the popularity of flavored e-cigarettes (Cullen et al., 2018; Dai and Hao, 2016) and our data detail that this preference continues into young adulthood. The use of flavored e-cigarettes to support quitting, however, is less understood. More qualitative information is needed in order to understand the role that flavors may play in supporting quitting (Camenga et al., 2017). While e-cigarettes are not a federally approved cessation method in the US, a limited number of studies suggest that the use of e-cigarettes could help smokers quit conventional cigarettes (Hajek et al., 2019; Subialka Nowariak et al., 2018), while other studies report mixed results on e-cigarettes’ potential to support quitting (Brandon et al., 2019; Brady et al., 2019; Giovenco and Delnevo, 2018). The use of flavored e-cigarettes appears to be associated with smokers’ intention to quit (Camenga et al., 2017; Chen, 2018), and our study further demonstrates that smoking status is also associated with flavor use among past 30 day e-cigarette users. These findings underscore the need for more research to better understand the role that flavors play in the quitting process.

Our data, along with the recent Surgeon General advisory and other state and national findings, demonstrate the need for regulation of e-cigarettes products (U.S., 2018). Nicotine poses a significant risk to youth and young adults and efforts are needed to restrict access to products that are appealing to this age group. Restricting or banning the sale of flavored e-cigarettes and/or increasing the purchasing age to 21,

are needed to prevent initiation to addictive levels of nicotine at early ages (National Academies of Sciences E Medicine, 2018; Institute of Medicine, 2015). Furthermore, efforts must be taken to communicate that never smokers should not use e-cigarettes (CfDca, 2019). Finally, claims that e-cigarettes help established smokers quit, are weakened by declining trends of current smokers use of the product as illustrated by MATS data. E-cigarette companies must be held to the same standard for other cessation products to independently and scientifically demonstrate their cessation benefit to federal regulators. Meanwhile, ongoing surveillance is essential as the market continues to evolve and manufacturer applications for FDA pre-market approval are determined. Efforts at all levels are needed to ensure that e-cigarette use among youth and younger adults, including those who have never used a tobacco product prior to using e-cigarettes, do not face long-term addiction to nicotine and progression on to more harmful forms of tobacco products.

## 5. Limitations

This study is subject to a few limitations. First, data for this study were collected by telephone and respondents may feel compelled to provide answers that are socially acceptable. However, it has been documented that self-reported tobacco use is as reliable as biochemically validated responses (Ramo et al., 2011). Secondly, due to instrument changes between survey rounds, it was not possible to directly compare the use of flavored e-cigarettes between 2014 and 2018. Similarly, detailed information on the specific flavor used was not collected; therefore, findings can only specify whether products were flavored or unflavored. This study is limited by sample size in understanding the use of multiple products, frequency of use, and which flavors are utilized by those intending to quit. MATS also asked about e-cigarette use broadly and defined an e-cigarette as a battery-powered device that produces vapor instead of smoke. No information was collected on the specific model or brand of e-cigarette. MATS, along with other state and national surveys, struggles to accurately define and measure the use of this emerging field of products (Huang et al., 2019). Finally, since MATS is a population-based survey and Minnesota is predominately white, it is difficult to calculate reliable estimates by race and ethnicity. There may be meaningful differences within population groups that cannot be detected by this survey and findings may not be generalizable outside Minnesota.

## 6. Conclusion

While the overall use of e-cigarettes was unchanged among representative statewide samples of adults in Minnesota between 2014 and 2018, important shifts in patterns of use occurred by frequency of use, age, and smoking status. Larger percentages of young adults and never smokers (tobacco-naïve) are using e-cigarettes. It is essential to continue to monitor e-cigarette use by demographics, frequency and flavors, especially as the marketplace continues to evolve. Tobacco control researchers, advocates and policy makers need to pay close attention to shifting trends as additional policies and tobacco control efforts are considered.

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