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# Impact of the FDA flavour enforcement policy on flavoured electronic cigarette use behaviour changes

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## ABSTRACT

**Introduction** This study aims to investigate electronic cigarette (e-cigarette) use behaviour changes after the implementation of the US Food and Drug Administration (FDA) restriction on the sale of all unauthorised flavoured cartridge-based e-cigarettes other than tobacco and menthol flavour on 6 February 2020, as well as factors associated with these changes.

**Methods** Through Amazon's Mechanical Turk service, 3533 current adult flavoured e-cigarette users (who were not exclusive tobacco-flavoured or menthol-flavoured e-cigarette users) were recruited for an online survey from 8 July to 29 July 2021. Multiple logistic regression models were used to identify significant factors associated with quitting e-cigarette use, switching to other flavoured electronic nicotine delivery system (ENDS) products, switching to combustible tobacco products, switching to menthol-flavoured e-cigarettes and switching to tobacco-flavoured e-cigarettes.

**Results** Resulting from the FDA flavour enforcement policy, the top four e-cigarette use behaviour changes were: (1) switching to other flavoured ENDS products such as the tank system or disposable e-cigarettes (29.24%), (2) switching to menthol-flavoured pod systems (18.09%), (3) switching to combustible tobacco products (14.12%) and (4) switching to tobacco-flavoured pod systems (12.03%). There were 4.9% participants who indicated that they quit e-cigarette use. Overall, multiple factors, especially past 30-day use of certain flavours, were associated with different behaviour changes.

**Conclusions** The implementation of the FDA flavour enforcement policy on cartridge-based e-cigarette was associated with significant e-cigarette behaviour changes, with multiple factors being associated with these changes. These results provide important information for future regulations of flavoured e-cigarette products.

## INTRODUCTION

Electronic cigarettes (e-cigarettes) are non-combustible battery-operated tobacco products where liquid (e-liquid), usually consisting of propylene glycol, vegetable glycerol, nicotine and flavouring chemicals, is heated and inhaled.<sup>1</sup> E-cigarettes, promoted as an alternative to smoking, have rapidly gained popularity in the USA in recent years, especially among youth and young adults.<sup>2</sup> The 2020 National Youth Tobacco Survey in the USA showed that approximately 19.6% of high school students and 4.7% of middle school students were current e-cigarette users.<sup>3</sup> In 2018, 3.2% of adults were current e-cigarette users and 14.9% of adults were ever e-cigarette users in

## WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ On 6 February 2020, the US Food and Drug Administration (FDA) restricted the sale of all unauthorised flavoured cartridge-based electronic cigarettes (e-cigarettes) other than tobacco and menthol flavours.

## WHAT THIS STUDY ADDS

⇒ The FDA flavour enforcement policy led to significant e-cigarette use behaviour changes.  
⇒ Switching to other flavoured e-cigarettes or menthol-flavoured pod systems were the top two changes for both exclusive e-cigarette users and dual users.

## HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our findings provide an initial but important evaluation of the impact of the FDA flavour enforcement policy on e-cigarette behaviour changes.

the USA.<sup>4</sup> Recent mouse and cell line research on e-cigarettes have found that e-liquids could lead to cytotoxicity and inflammation in lung epithelial cells, affect the cardiovascular system and possibly lead to cancer.<sup>5–13</sup> Human studies have also found associations of e-cigarette use with self-reported wheezing, asthma and chronic obstructive pulmonary disease.<sup>5 14–18</sup>

Flavours play an important role in the initiation and progression of e-cigarette use. An online survey conducted in 2016 showed 29.5% adult e-cigarette users selected flavour as a primary reason for initiating e-cigarette use.<sup>19</sup> A cross-sectional survey in Texas showed that young adults started their first e-cigarettes with non-tobacco flavours, predominantly fruit and candy flavours.<sup>20</sup> While tobacco and menthol flavours were the most popular flavours for initiating e-cigarette use before 2013, fruit became the most popular flavour for first-time e-cigarette users in recent years.<sup>21</sup> To curtail the rapid rise of e-cigarette use in youth, on 2 January 2020, the US Food and Drug Administration (FDA) issued a policy prioritising enforcement against the sale of unauthorised flavoured cartridge-based e-cigarettes other than those with tobacco or menthol flavour.<sup>22</sup> This FDA flavour enforcement policy was implemented on 6 February 2020. A previous mixed methods study conducted in 2020 on adult JUUL users before and after the FDA flavour enforcement policy found a significant decrease in the use of mint pods and a significant increase in the use of menthol pods, as well as switching to products with desired



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flavours (including fruit and dessert flavours) such as generic pods or disposable e-cigarettes,<sup>23</sup> which were not included in the regulations. Another online study conducted in San Francisco with 247 young adults aged 18–34 years found most flavoured e-cigarette users were still able to obtain flavoured tobacco products in multiple ways after the FDA, state and local flavour bans.<sup>24</sup>

This study aims to evaluate the impact of the FDA flavour enforcement policy on current adult e-cigarette users' e-cigarette use, as well as to identify factors associated with these changes. Using an online anonymous cross-sectional survey with questions derived from standardised national survey questionnaires, our study examined current flavoured e-cigarette users' behaviour changes ranging from quitting e-cigarette use to switching to other flavoured electronic nicotine delivery system (ENDS) products, menthol or tobacco flavoured e-cigarettes or combustible tobacco products, and sought to identify potential factors such as past 30-day e-cigarette flavour use and demographic characteristics associated with these changes. This study contributes to the growing literature evaluating the impacts of such restrictions on flavoured e-cigarette use.

## METHODS

### Study population

To examine flavoured e-cigarette use behaviour changes after the FDA flavour enforcement policy, we conducted a Research Electronic Data Capture online survey through Amazon's Mechanical Turk (MTurk) from 8 July to 29 July 2021. The majority of the survey questions were taken from either the Population Assessment of Tobacco and Health (PATH) Study or the Behavioural Risk Factor Surveillance System national survey.<sup>25 26</sup> The eligibility criteria for participating in this online survey were (1) currently aged 18 years or older; (2) being an ever or current e-cigarette user and (3) currently living in the USA. To ensure the quality of the data, we further applied the following criteria for MTurk survey participants: (1) having a Human Intelligence Task (HIT) approval rate >90<sup>27</sup> and (2) having number of HITs approved >50 ('HIT approval rate >90' means the MTurk worker have >90 approved tasks get paid if the worker conducted 100 tasks. 'Having number of HITs approved >50' means that the MTurk worker has >50 approved tasks. To ensure we have high-quality data from the MTurk survey, we have these two qualification criteria for MTurk workers to be eligible to participate in our study). The participants were allowed to answer all of the questions within 2 hours and were paid US\$2 for completing the online survey. A total of 7389 subjects answered the eligibility survey; of these, 6569 (88.9%) were eligible. Among the 6569 eligible subjects, 5448 (82.9%) completed the main survey questionnaire. Of these, subjects were excluded if they: (1) answered 'yes' to the ever e-cigarette use question in the screening survey but answered 'no' to the ever e-cigarette use question in the main questionnaire (n=399), (2) were not current daily or someday e-cigarette users (n=691) or (3) exclusively used tobacco or menthol flavoured e-cigarettes in the past 30 days, because tobacco and menthol flavours are not restricted by the FDA flavour enforcement (n=825). Our final analyses were thus conducted for 3533 adults who were used e-cigarettes daily or some days, used restricted flavours and met all other study criteria (online supplemental figure 1).

### Outcome variables

The outcome variable was e-cigarette user's behaviour changes after the implementation of the FDA flavour enforcement policy,

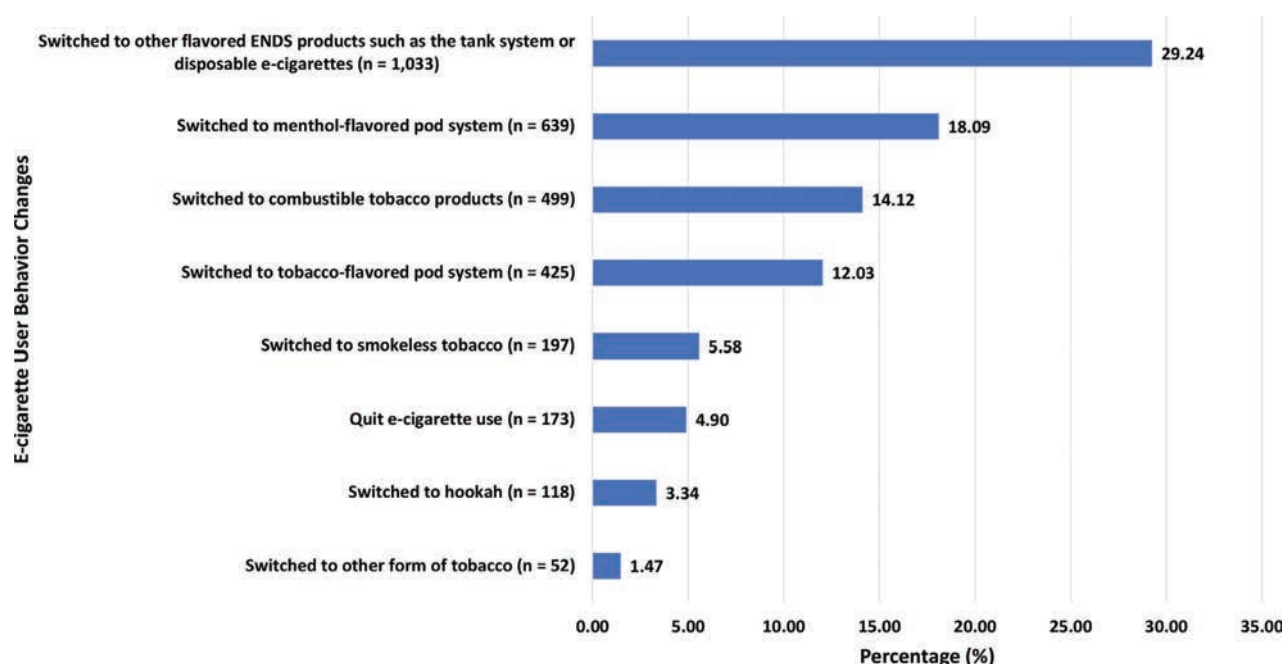
which was based on the survey question "If you have been using flavoured e-cigarettes or other electronic nicotine products (other than tobacco or menthol) that fell within the FDA flavour enforcement policy, what did you do after the FDA flavour enforcement policy was implemented on 6 February 2020?" We first described the FDA flavour enforcement policy to the survey participants before they completed the questions. The possible answers to this question included: '(1) switched to tobacco-flavoured pod system, (2) switched to menthol-flavoured pod system, (3) switched to other flavoured ENDS products such as the tank system or disposable e-cigarettes, (4) switched to combustible tobacco products (such as cigarettes, cigars, cigarillos, filtered cigars or pipe tobacco), (5) switched to smokeless tobacco such as snus, dip, spit or chew, (6) switched to hookah, (7) switched to other form of tobacco, (8) quit e-cigarette use, (9) other, (10) do not know'. Participants were only allowed to choose one option. We created five binary (yes/no) outcome variables for the top five behaviour change options: (1) switched to other flavoured ENDS products, (2) switched to a menthol-flavoured pod system, (3) quit e-cigarette use, (4) switched to combustible tobacco products and (5) switched to a tobacco-flavoured pod system.

### PREDICTOR VARIABLES

We examined users' past 30-day e-cigarette flavour use, including menthol, mint, tobacco, coffee, apple, mango, strawberry, lemon, orange, kiwi, coconut, banana, grape, peach, watermelon, pineapple, chocolate, vanilla, cotton candy and unflavored. Participants were allowed to choose multiple flavours. Binary past 30-day flavour use variables were created to denote whether the participant used one specific flavour or not. Other variables included general demographic information, tobacco use status (for all tobacco products) and behaviours, risk perceptions of tobacco product use, opinions on FDA flavour enforcement policy and home and car smoking and vaping policies. Demographic information included age, gender, race/ethnicity, marital status, income, pregnancy status, education level, employment status, general health, physical health and mental health. The tobacco use status included smoking status, length of smoking, whether subject completely quit smoking, type of e-cigarette device, reasons for e-cigarette use, length of e-cigarette use, nicotine concentration used in e-cigarette, propylene glycol/vegetable glycerine ratio of e-cigarettes, first e-cigarette flavour used, last e-cigarette flavour used before quitting e-cigarettes for those participants who have quit e-cigarette use, past 30-day e-cigarette flavour use, whether the subject has ever tried a e-cigarette flavour that made them feel sick and tobacco product use inside the home. Risk perceptions of tobacco product use included harmful health perceptions of smoking, e-cigarettes, nicotine, menthol and mint. Opinions on the FDA flavour enforcement policy were measured using a 5-point Likert scale. The home and car smoking and vaping policies included questions on rules on smoking or vaping inside home or vehicles, as well as whether rules on smoking or vaping inside home or car changed after the implementation of the FDA flavour enforcement policy.

### STATISTICAL ANALYSIS

To examine the bivariate association of risk factors with e-cigarette use behaviour changes,  $\chi^2$  tests were used. Purposeful model selection method was used to select significant variables associated with e-cigarette use behaviour changes.<sup>28</sup> The variance inflation factor values were used to examine potential multicollinearities among predictor variables. Logistic regression models



**Figure 1** E-cigarette use behaviour changes with the Food and Drug Administration flavour enforcement policy (n=3533). ENDS, electronic nicotine delivery system.

were used to examine important factors associated with e-cigarette use behaviour changes. All data analyses were conducted using statistical analysis software SAS V.9.4 (SAS Institute, Cary, North Carolina, USA) at the significance level of 5% for two-sided tests.

## RESULTS

### Flavoured e-cigarette use behaviour changes due to FDA flavour enforcement policy

Figure 1 shows percentage of different e-cigarette users' behaviour changes after the implementation of the FDA flavour enforcement policy for the 3533 current adult e-cigarette users who were not exclusive tobacco-flavoured or menthol-flavoured e-cigarette users. Among these, 1033 (29.24%) switched to other flavoured ENDS products such as the tank system or disposable e-cigarettes, 639 (18.09%) switched to menthol-flavoured pod system, 499 (14.12%) switched to combustible tobacco product use, 425 (12.03%) switched to tobacco-flavoured pod system use, 197 (5.58%) switched to smokeless tobacco such as snus, dip, spit or chew, 173 (4.90%) quit e-cigarette use, 118 (3.34%) switched to hookah and 52 (1.47%) switched to other forms of tobacco products. Among the 512 exclusive e-cigarette users, 169 (33.01%) switched to other flavoured ENDS products, 60 (11.72%) switched to a menthol-flavoured pod system, 55 (10.74%) quit e-cigarette use, 22 (4.30%) switched to a tobacco-flavoured pod system, 19 (3.71%) switched to hookah, 16 (3.13%) switched to combustible tobacco products use, 7 (1.37%) switched to smokeless tobacco and 4 (0.78%) switched to other forms of tobacco. For the 3014 dual users who both smoked and used e-cigarettes, 863 (28.63%) switched to other flavoured ENDS products, 578 (19.18%) switched to a menthol-flavoured pod system, 482 (15.99%) switched to combustible tobacco products use, 403 (13.37%) switched to a tobacco-flavoured pod system, 190 (6.30%) switched to smokeless tobacco, 118

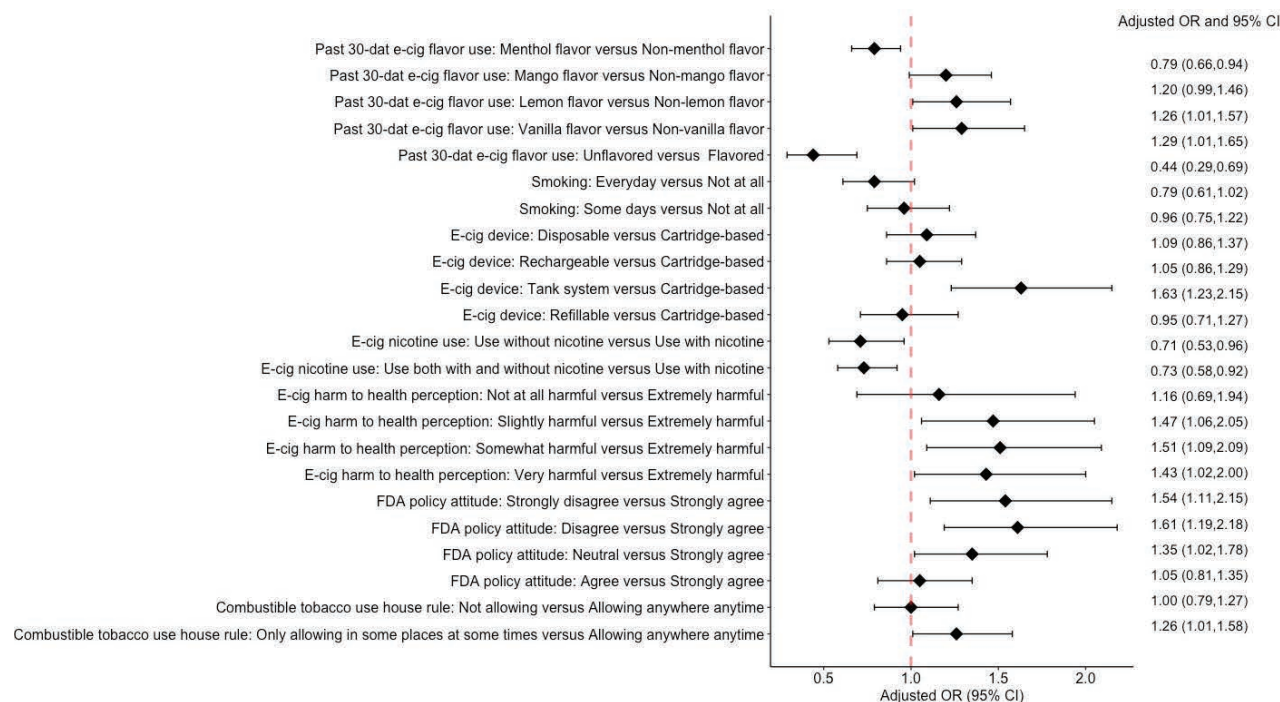
(3.92%) quit e-cigarette use, 99 (3.28%) switched to hookah and 48 (1.59%) switched to other forms of tobacco.

Online supplemental table 1 shows the sample characteristics of the 3533 current adult flavoured e-cigarette users who did not exclusively use either tobacco or menthol flavours, as well as the bivariate associations of sample characteristics with e-cigarette use behaviour changes based on  $\chi^2$  tests.

We also examined the quality of our survey questions. About 92% of the participants thought our survey questions were understandable and did not have to read the item more than once to understand what it was asking. Over 95% of the participants thought the meaning of our survey questions were clear and straightforward. Around 93% of the participants felt the scales used to answer the questions were adequate.

### Associations of sample characteristics with e-cigarette use behaviour changes

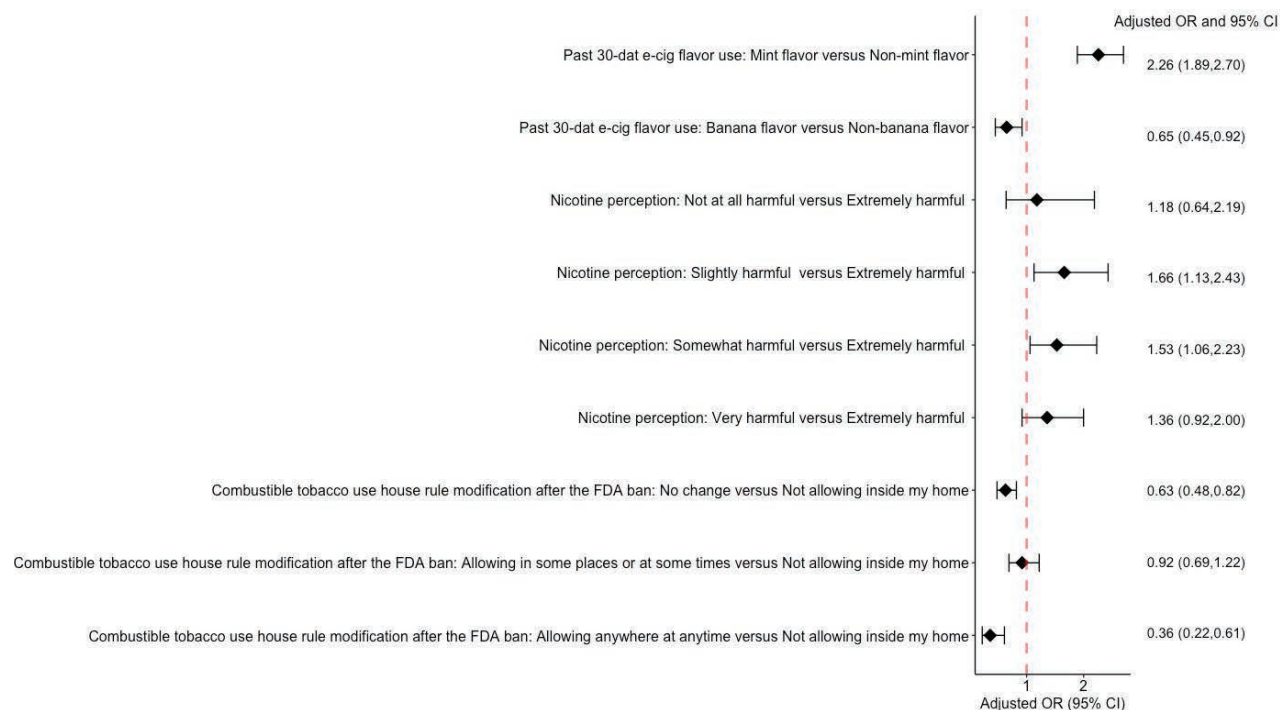
We used multiple logistic regression models to examine factors associated with different use behaviour changes because of the implementation of the FDA flavour enforcement policy. Figure 2 shows variables significantly associated with switching to other flavoured ENDS products. Both past 30-day menthol-flavoured (OR=0.79, 95% CI: 0.66 to 0.94) and unflavoured (OR=0.44, 95% CI: 0.29 to 0.69) e-cigarette users were less likely to switch to other flavoured ENDS products, while lemon-flavoured (OR=1.26, 95% CI: 1.01 to 1.57) and vanilla-flavoured (OR=1.29, 95% CI: 1.01 to 1.65) e-cigarette users were more likely to switch to other flavoured ENDS products. Tank system e-cigarette users (OR=1.63, 95% CI: 1.23 to 2.15), more harmful perception of e-cigarette use and health (OR=1.43, 95% CI: 1.02 to 2.00), disagreeing with the FDA flavour enforcement policy (OR=1.54, 95% CI: 1.11 to 2.15) and less strict combustible tobacco product use inside the home (OR=1.26, 95% CI: 1.01 to 1.58) were all associated with a higher likelihood of switching to other



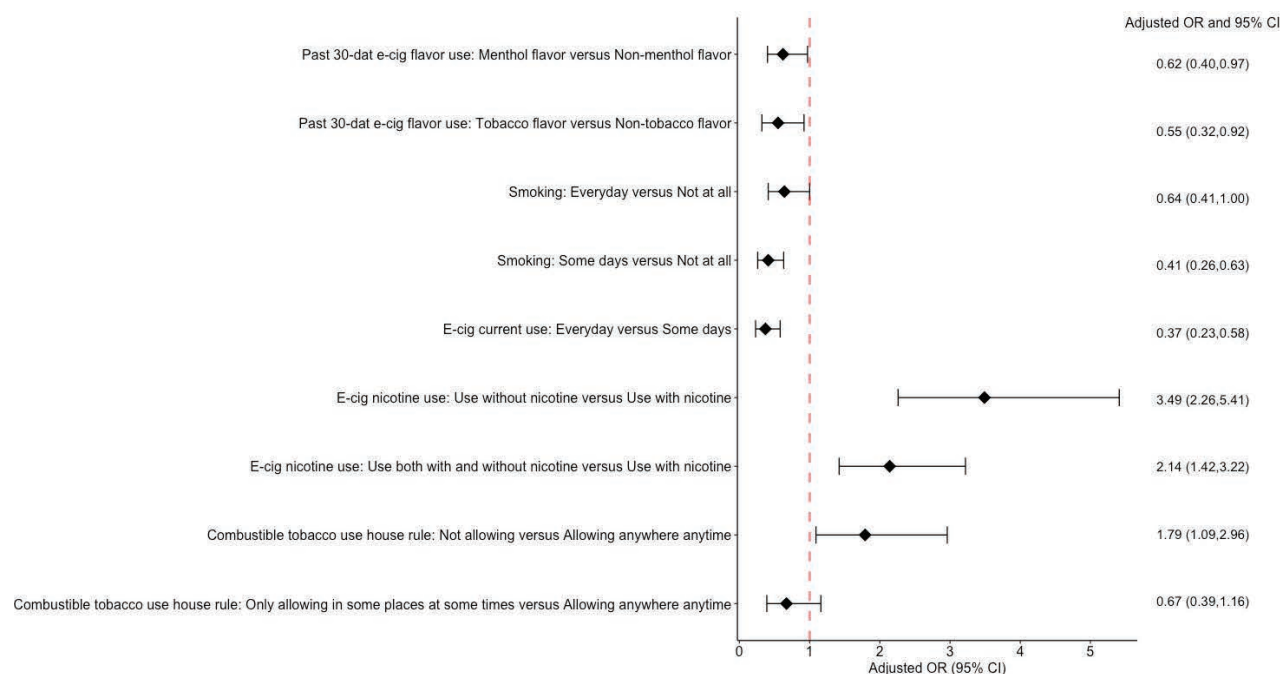
**Figure 2** Adjusted ORs and corresponding 95% CIs for switching to other flavoured electronic nicotine delivery system products such as the tank system and disposable e-cigarettes (e-cig) (n=3302). FDA, Food and Drug Administration.

flavoured ENDS products. Less use (OR=0.73, 95% CI: 0.58 to 0.92) or no use (OR=0.71, 95% CI: 0.53 to 0.96) of nicotine in e-cigarettes were associated with lower likelihood of switching to other flavoured ENDS products.

Figure 3 shows that past 30-day mint flavoured e-cigarette use (OR=2.26, 95% CI: 1.89 to 2.70) or less harmful nicotine perception (OR=1.66, 95% CI: 1.13 to 2.43) were significantly associated with higher likelihood of switching to menthol-flavoured



**Figure 3** Adjusted ORs and corresponding 95% CIs for switching to menthol-flavoured e-cigarettes (e-cig) (n=3420). FDA, Food and Drug Administration.



**Figure 4** Adjusted ORs and corresponding 95% CIs for quitting e-cigarette (e-cig) use (n=3370).

e-cigarette use. Adults who used banana-flavoured e-cigarettes in the past 30 days (OR=0.65, 95% CI: 0.45 to 0.92), or had no change (OR=0.63, 95% CI: 0.48 to 0.82) or became less restrictive in their home rule regarding combustible tobacco product use (OR=0.36, 95% CI: 0.22 to 0.61) were less likely to switch to menthol-flavoured e-cigarette use.

Both past 30-day menthol-flavoured (OR=0.62, 95% CI: 0.40 to 0.97) and tobacco-flavoured (OR=0.55, 95% CI: 0.32 to 0.92) e-cigarette use was significantly associated with lower likelihood of quitting e-cigarettes (figure 4). Smoking every day (OR=0.64, 95% CI: 0.41 to 1.00) or some days (OR=0.41, 95% CI: 0.26 to 0.63) also decreased the likelihood of quitting e-cigarettes. Similarly, using e-cigarettes every day lowered the likelihood of quitting e-cigarettes compared with using e-cigarettes some days (OR=0.37, 95% CI: 0.23 to 0.58). Current adult e-cigarette users who used flavoured e-cigarettes without nicotine had a higher likelihood of quitting e-cigarettes (OR=3.49, 95% CI: 2.26 to 5.41), as did current adult e-cigarette users who did not allow combustible tobacco product use inside their home (OR=1.79, 95% CI: 1.09 to 2.96).

Current adult e-cigarette users who used mango-flavoured e-cigarettes in the past 30 days (OR=1.31, 95% CI: 1.03 to 1.67), smoked every day (OR=5.04, 95% CI: 2.92 to 8.70) or some days (OR=4.52, 95% CI: 2.62 to 7.80), or had changed their combustible tobacco product use inside the home to be less stringent (OR=2.64, 95% CI: 1.69 to 4.10) had higher likelihoods of switching to combustible tobacco product use (figure 5). However, current adult e-cigarette users who used e-cigarettes every day (OR=0.74, 95% CI: 0.59 to 0.93) or currently used disposable e-cigarettes (OR=0.51, 95% CI: 0.37 to 0.70) were less likely to switch to combustible tobacco product.

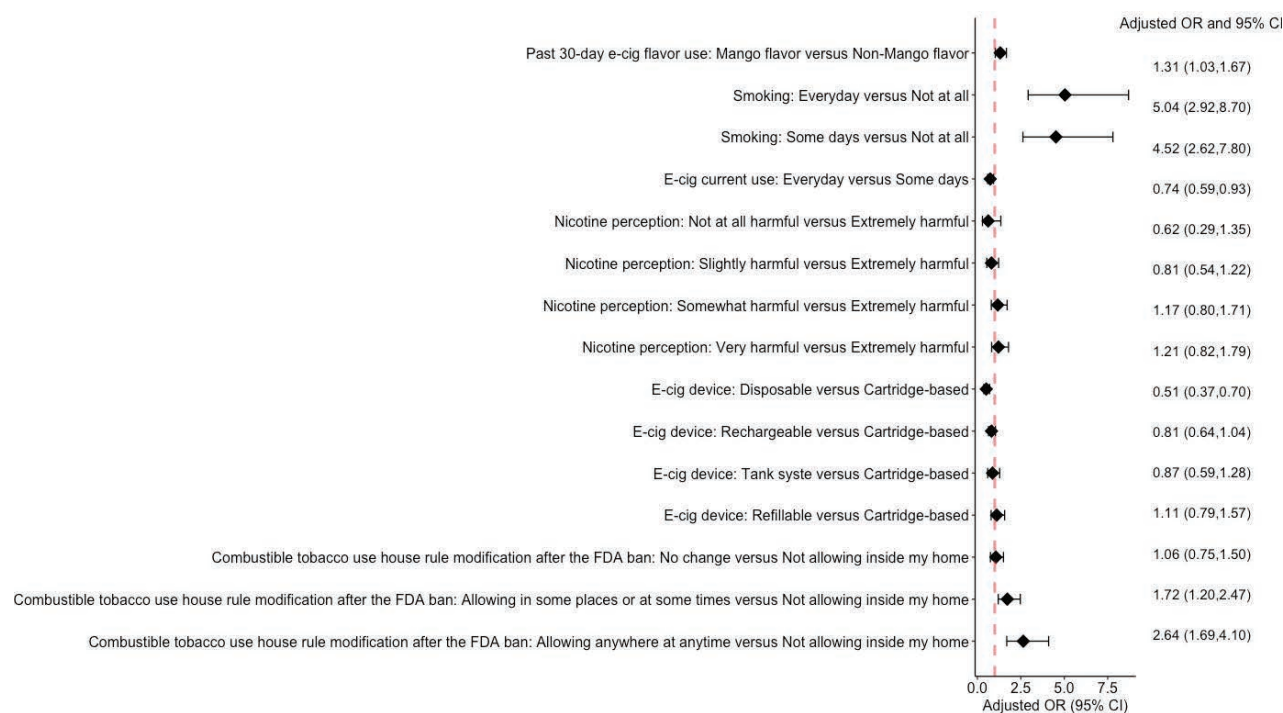
Past 30 days lemon-flavoured e-cigarette users (OR=0.62, 95% CI: 0.44 to 0.88) were less likely to switch to tobacco-flavoured e-cigarettes (online supplemental figure 2). Less healthy mental health (OR=0.60, 95% CI: 0.36 to 0.99), no change (OR=0.58, 95% CI: 0.43 to 0.79) or changing to less restricted

combustible tobacco product use inside the home (OR=0.66, 95% CI: 0.48 to 0.92) or less restricted vaping rule inside the vehicle (OR=0.63, 95% CI: 0.47 to 0.86) were also associated with lower likelihood of switching to tobacco-flavoured e-cigarettes use. Conversely, smoking every day (OR=3.26, 95% CI: 1.99 to 5.32) or some days (OR=2.00, 95% CI: 1.22 to 3.27), or using disposable e-cigarettes (OR=1.70, 95% CI: 1.24 to 2.34) were associated with higher likelihood of switching to tobacco-flavoured e-cigarettes.

## DISCUSSION

Our study investigated current adult e-cigarette users' behaviour changes after the implementation of the FDA flavour enforcement policy using an online survey under the assumption that there were e-cigarette use behaviour changes after the FDA flavour enforcement policy. We identified several major behaviour changes, including switching to other flavoured ENDS products such as the tank system or disposable e-cigarettes, switching to menthol-flavoured pod systems, switching to tobacco-flavoured pod systems, switching to combustible tobacco products, switching to smokeless tobacco or quitting e-cigarette use. For both exclusive e-cigarette users and dual users, the top two behaviour changes were switching to other flavoured ENDS products and switching to menthol-flavoured pod systems. Our results also suggest that the FDA flavour enforcement policy could drive some cigarette smokers who might benefit from using flavoured e-cigarettes for harm reduction purposes back to cigarette smoking.

A previous online survey study on 1005 adult New Zealanders showed a major role of flavours in e-cigarette use initiation for both smokers, former smokers and non-smokers.<sup>29</sup> Our study found past 30-day e-cigarette flavour use was significantly associated with e-cigarette users' behaviour changes. As expected, past 30-day menthol-flavoured or tobacco-flavoured e-cigarette users were less likely to quit e-cigarette use as the policy



**Figure 5** Adjusted ORs and corresponding 95% CIs for switching to combustible tobacco products (n=3392). E-cig, electronic cigarette; FDA, Food and Drug Administration.

does not apply to tobacco-flavoured and menthol-flavoured cartridge-based e-cigarettes. Similarly, we found that past 30-day lemon-flavoured and vanilla-flavoured e-cigarette users were more likely to switch to other flavoured ENDS products, while menthol-flavoured or unflavoured e-cigarette users were less likely to switch to other flavoured ENDS products such as the tank system or disposable e-cigarettes. Lemon-flavoured e-cigarette users were also less likely to switch to tobacco-flavoured e-cigarettes. Mint-flavoured e-cigarette users were more likely to switch to menthol-flavoured e-cigarettes, likely due to the similarity between menthol and mint flavours. Banana-flavoured e-cigarette users were less likely to switch to menthol-flavoured e-cigarettes. We showed that mango-flavoured e-cigarette users were more likely to switch to combustible tobacco product use. Our results provided important evidence regarding the association of specific flavour use in the past 30 days with e-cigarette use behaviour changes after the FDA flavour enforcement policy. Other important factors associated with use behaviour changes included mental health, smoking status, nicotine harm perception, e-cigarette harm perception, e-cigarette device type, vaping rule inside the vehicle, combustible tobacco product use rule inside the home and attitude towards the FDA flavour enforcement policy.

Most previous e-cigarette flavour prevalence examinations focused on large categories of e-cigarette flavours such as fruit, candy/sweet, tobacco and menthol/mint, while few examined specific e-cigarette flavours such as mango, lemon, banana, vanilla, etc. One previous study based on the PATH Study Wave 3 data showed fruit flavour is the most popular e-cigarette flavour category in both youth and adults.<sup>30</sup> Our previous examination of Reddit (a popular social media platform for users to share their experiences) data showed mango flavour was the most popular JUUL (the most popular cartridge-based e-cigarette brand before the FDA flavour enforcement policy) flavour

within the fruit flavour category.<sup>31</sup> JUUL pulled mango and other fruit flavoured e-cigarettes from the market in October 2019, well before the announcement of the FDA flavour enforcement policy. After the implementation of the FDA flavour enforcement policy, flavoured disposable e-cigarettes became popular among e-cigarette users as they were not restricted by the FDA flavour enforcement policy. The e-cigarette unit sales data showed the increased sales of disposable e-cigarettes in 2020, especially after the FDA flavour enforcement policy.<sup>32</sup> As flavours are one of the major reasons attracting users to initiate e-cigarette use, it is not surprising that the first ranked e-cigarette use behaviour change was to switch to other ENDS products such as the tank system or disposable e-cigarettes where flavours were still available. In addition, most of our current adult e-cigarette users were also smokers; thus, it might not be difficult for them to switch to either tobacco or menthol flavoured e-cigarettes, as those are the two flavours currently available in cigarettes. Our findings that mango-flavoured e-cigarette users were more likely to switch to combustible tobacco products might be due to their dislike of both the tobacco-flavoured and menthol-flavoured e-cigarettes, or the availability of the mango-flavoured or other fruit-flavoured cigars on the market, or other unknown reasons need to be further explored.

Our results showed that the nicotine use in e-cigarettes is one of the major reasons for continued e-cigarette use after the FDA flavour enforcement policy, as current adult e-cigarette users who used e-cigarettes without nicotine were more likely to quit e-cigarette use after the FDA flavour enforcement policy. Participants who were more restrictive regarding secondhand exposure to combustible tobacco product use inside home were more likely to quit e-cigarettes. Our results indicated that less harm perception of nicotine and e-cigarette use to health, disagreement with the FDA flavour enforcement policy, and restrictions regarding secondhand exposure to tobacco products all contribute to

continued use of e-cigarettes. It is interesting to notice that more e-cigarette users changed to less restrictive home smoking policy after the implementation of the FDA flavour enforcement policy, which needs further exploration in future studies. In addition, we showed that both smoking and less restrictions on second-hand exposure also contributed to switching to combustible tobacco product use.

There are several limitations in our current study. First, our study assumes that there was actual behaviour change after the FDA flavour enforcement policy. However, flavoured cartridge-based e-cigarettes were still available in the market and e-cigarette users were still able to obtain them from online retailers or illegal markets.<sup>24</sup> Our question does not include the option of 'no change' in their behaviours, although they might choose 'other' in this situation. Second, this is a cross-sectional self-reported online survey study, which might be subject to some reporting bias. Third, our data were collected through MTurk, which represent current adult e-cigarette users using their time to complete online surveys in the USA. Moreover, we did not examine the use behaviour changes for those youth e-cigarette users, which should be an important future research direction. Fourth, a large proportion of participants used more than one specific flavour, thus we created binary variables for each specific flavour. The associations we observed between the specific flavours and use behaviour changes might not be solely due to exclusive use of that specific flavour. Fifth, participants might opt to multiple behaviour changes after the FDA flavour enforcement policy such as switching to both menthol-flavoured and tobacco-flavoured e-cigarettes. Our user behaviour change question did not cover this situation. Lastly, we did not include the effect of local or state policies, such as the flavour ban in New York State or New York City on flavoured ENDS products in addition to the FDA flavour enforcement policy. Thus, some behaviour changes might be the additive impact of both local or state policy and the FDA flavour enforcement policy.

Results from our investigation inform FDA current e-cigarette use behaviour changes after the FDA flavour enforcement policy implemented, and provide FDA important information and evidence for further regulatory actions on tobacco products to protect public health. The continued availability of other types flavoured e-cigarettes, such as disposable e-cigarettes, on the market allows current e-cigarette users to continue to use flavoured e-cigarettes users. This indicates that a more restricted policy on all flavoured vaping products might be more effective in reducing flavoured e-cigarette use. The relatively large proportion of e-cigarette users switching to menthol-flavoured e-cigarette use indicates that menthol flavour has the potential to attract and maintain the e-cigarette use. Further restriction of menthol-flavoured e-cigarettes sales might help reduce e-cigarette use.

## CONCLUSION

Our study examined the impact of the FDA flavour enforcement policy on flavoured e-cigarette users' behaviour changes. Switching to other flavoured ENDS products and menthol-flavoured pod system were the top two use behaviour changes after the implementation of the FDA flavour enforcement policy. Past 30-day e-cigarette flavour use appears to be an important contributing factor to different e-cigarette use behaviour changes. Our results can be informative to the FDA regarding the effects of the tobacco regulatory policy on use behaviour changes, and important factors that contributed to different use behaviour changes. Our study results provide important guidance

for future FDA e-cigarette regulation policies to protect public health. A more restricted ban on all flavoured tobacco products such as hookah, cigar, etc, particularly flavoured vaping products, could potentially help reduce the uptake of tobacco and ENDS products, especially in youth and young adults.

**Contributors** DL, DO, MB-T and ZX: conceived and designed the study; DL and ZX: analysed the data; DL and ZX: wrote the manuscript; DL, DO, MB-T and ZX: edited the manuscript. DL will be responsible for the overall content as the guarantor.

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**Disclaimer** The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH or the FDA.

**Competing interests** No, there are no competing interests.

**Patient consent for publication** Consent obtained directly from patient(s)

**Ethics approval** Study questionnaires and materials were reviewed and approved by the Office for Human Subject Protection Research Subjects Review Board (RSRB) at the University of Rochester (Study ID: Study00005352). Participants gave informed consent to participate in the study before taking part.

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