

# BMJ Open Impact of non-menthol flavours in e-cigarettes on perceptions and use: an updated systematic review

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## ABSTRACT

**Objectives** Given the exponential increase in the use of e-cigarettes among younger age groups and in the growth in research on e-cigarette flavours, we conducted a systematic review examining the impact of non-menthol flavoured e-cigarettes on e-cigarette perceptions and use among youth and adults.

**Design** PubMed, Embase, PsycINFO and CINAHL were systematically searched for studies published and indexed through March 2018.

**Eligibility criteria** Quantitative observational and experimental studies that assessed the effect of non-menthol flavours in e-cigarettes on perceptions and use behaviours were included. Specific outcome measures assessed are appeal, reasons for use, risk perceptions, susceptibility, intention to try, initiation, preference, current use, quit intentions and cessation.

**Data extraction and synthesis** Three authors independently extracted data related to the impact of flavours in tobacco products. Data from a previous review were then combined with those from the updated review for final analysis. Results were then grouped and analysed by outcome measure.

**Results** The review included 51 articles for synthesis, including 17 published up to 2016 and an additional 34 published between 2016 and 2018. Results indicate that non-menthol flavours in e-cigarettes decrease harm perceptions (five studies) and increase willingness to try and initiation of e-cigarettes (six studies). Among adults, e-cigarette flavours increase product appeal (seven studies) and are a primary reason many adults use the product (five studies). The role of flavoured e-cigarettes on smoking cessation remains unclear (six studies).

**Conclusion** This review provides summary data on the role of non-menthol flavours in e-cigarette perceptions and use. Consistent evidence shows that flavours attract both youth and adults to use e-cigarettes. Given the clear findings that such flavours increase product appeal, willingness to try and initiation among youth, banning non-menthol flavours in e-cigarettes may reduce youth e-cigarette use. Longitudinal research is needed to examine any role flavours may play in quit behaviours among adults.

## INTRODUCTION

Despite a ban on non-menthol flavours in cigarettes, current regulations in the USA

## Strengths and limitations of this study

- This large comprehensive review included 51 final articles for synthesis, including 17 published up to 2016 and an additional 34 published between 2016 and 2018.
- The majority of studies were cross-sectional and were from convenience samples, limiting the ability to make causal inferences as well as the generalisability of findings from these articles.
- We used a quality assessment tool (QATSDD) to rate the quality of articles included in the review.
- Qualitative data, while excluded, could have provided additional contextual information to the conclusions.

allow for the sale of non-menthol flavours in other tobacco products, including e-cigarettes.<sup>1</sup> However, the US Food and Drug Administration (FDA) continues to seek out and prioritise research that explores the issue of non-menthol flavours in tobacco products other than cigarettes and as such has issued an advance notice of proposed rulemaking seeking comments on the role that flavours play in tobacco product use.<sup>2</sup> Similarly, in fall of 2018, the FDA proposed a policy framework that would only allow non-menthol flavoured e-cigarettes to be sold in age-restricted locations or online under heightened age verification standards.<sup>3</sup>

Some studies have shown that flavours are particularly appealing to youth and are cited as a primary reason for use among this age group.<sup>4</sup> The use of e-cigarettes among youth may be a gateway to future cigarette use,<sup>5,6</sup> and nicotine (which is found in most e-cigarettes) is especially harmful to developing adolescent brains.<sup>7-9</sup> This makes the recent precipitous increase in e-cigarette use among youth particularly alarming.<sup>7</sup> Policymakers, including the FDA, are increasingly concerned about the rise in popularity of pod-type e-cigarette devices (eg, Juul), which



now own a large market share and deliver more nicotine than older generations of e-cigarettes.<sup>10 11</sup>

E-cigarettes are also regarded by many experts in tobacco control as a potential means of harm reduction among adult smokers if they use e-cigarettes to transition away from combustible tobacco products.<sup>12</sup> A few studies have suggested a positive association between e-cigarettes and quitting behaviours, including a recent randomised controlled trial.<sup>13–16</sup> Unravelling the relationship between potential harms or benefits of e-cigarette use among adult smokers is important in the development of regulations for e-cigarettes and, in particular, regulations regarding product flavours.

It is well known that recent years have seen a precipitous increase in the use of e-cigarettes in the USA and other countries among both youth and adults.<sup>17</sup> Recent data suggest that 20.8% of US youth<sup>18</sup> and 4.5% of US adults are current e-cigarette users.<sup>19</sup> These numbers vary globally, with 5.9% of adults and 8.2% of adolescents in Poland but only 0.3% of adults in Indonesia reporting current use.<sup>20</sup> However, upward trajectories of use have been noted globally,<sup>20</sup> and this increase in use has coincided with an exponential rise in e-cigarette flavours, with over 7000 flavours existing.<sup>21</sup> Many of these flavours utilise names that may appeal to younger populations such as cotton candy, gummy bear, cookies 'n cream and other sweet-flavoured brands.<sup>21</sup> The intense public health interest in e-cigarettes' impact on the tobacco control landscape and population health has resulted in a sharp increase in research conducted on flavours and e-cigarettes. Given this changing landscape, we conducted a systematic review of non-menthol flavoured e-cigarettes that extends previous research<sup>4</sup> by providing evidence specific to e-cigarettes about the role of non-menthol flavours in appeal, harm perceptions, intentions, use and cessation among youth and adults in the USA and globally.

## METHODS

We used methods similar to previously published research<sup>4</sup> and implemented two alterations: (1) updated the range of eligible publication dates (with the original including articles ever published until 4 April 2016, and the current review including articles published and indexed on or after 4 April 2016), and (2) focused this review specifically on e-cigarettes rather than all tobacco products, based on the precipitous increase in literature on e-cigarettes, as well as the increase in use of these products among youth and adults. All data relevant to the study are included in the article or uploaded as online supplementary information.

### Eligibility criteria

We included observational and experimental studies that assessed the impact of non-menthol flavours in e-cigarettes on perceptions and use behaviours such as initiation, preference and cessation. We did not exclude studies

based on participant characteristics. Studies included populations of any age, race, sex, ethnicity or country.

We excluded the following types of articles: those that were not English-language; were not peer-reviewed (eg, dissertations, technical reports); did not contain original data about flavoured e-cigarettes (eg, editorials, commentaries, literature reviews); did not address the impact of flavours on e-cigarette perceptions and use behaviours (eg, biological/medical/chemical toxicology/animal studies, sales trends, effects of flavour bans); were related to smoking marijuana or limited findings to menthol flavoured e-cigarettes only. In order to maintain a semblance of consistency across studies examined, we chose to exclude articles that used qualitative study designs. Additionally, because menthol and tobacco are often treated differently as it relates to policy implementation (eg, in 2009, FDA banned characterising flavours except for tobacco and menthol in cigarettes) and is also often viewed separately from other flavours in the literature, this review excludes articles that examine just menthol as a flavour.<sup>22</sup> We do include tobacco flavor in this review because despite the regulatory differences, some literature chooses to include tobacco as a characterising flavour and we wanted to explore any potential relationships produced by the literature.

### Type of outcome measures and intervention

Outcome measures include perceptions about appeal, reasons for use and risk perceptions; susceptibility and intentions to try and use behaviours, including initiation, preference, current use, quit intentions and cessation.

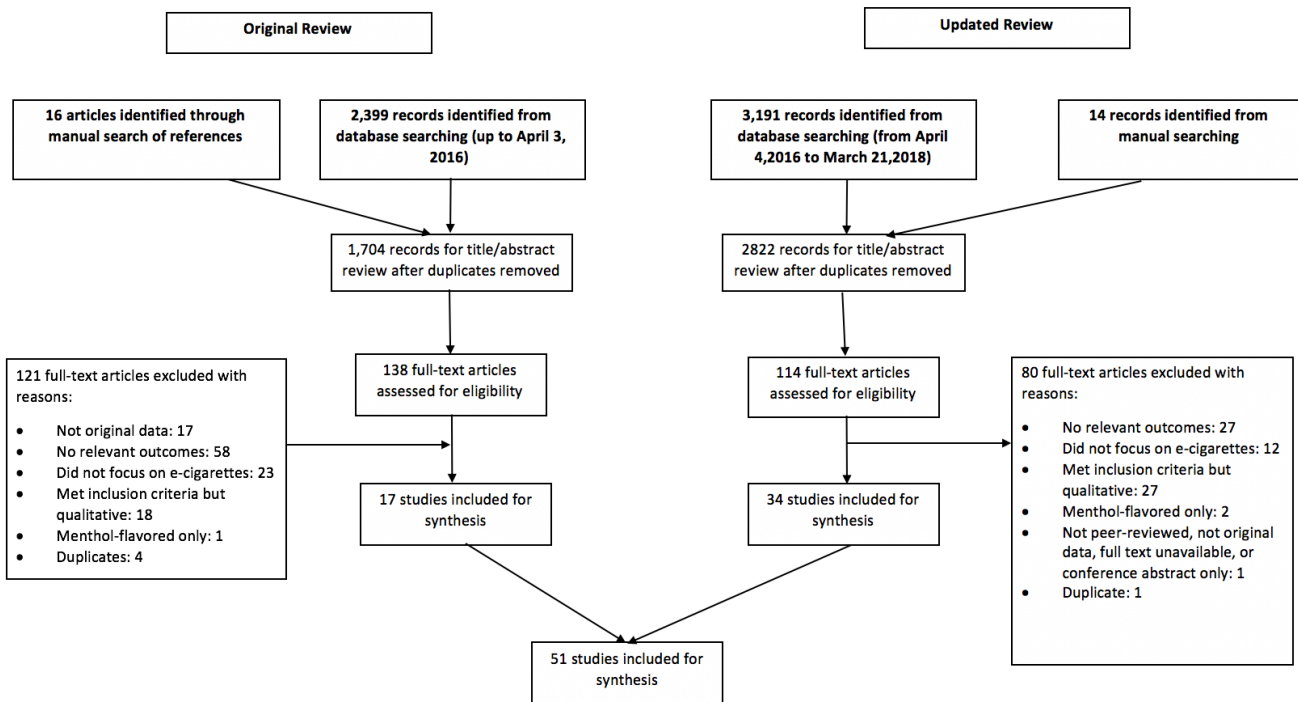
### Data sources and study selection

#### Literature search

One author (HMB) conducted searches of PubMed, Embase, PsycINFO and CINAHL for studies published and indexed in a database between 4 April 2016 and 12 March 2018. To maintain consistency with the previous systematic review, we maintained the same search string rather than modifying the search to include only e-cigarettes. We used Boolean language to connect variants of words related to tobacco products, use and flavour for PubMed, which was translated to match the search string requirements for other databases. A total of 3191 articles resulted from searching the four databases during the initial search (21 March 2018). After authors removed duplicates, 2822 articles remained for title and abstract review, including 14 articles identified through manual search of references.

#### Study selection

Two authors (CM and HMB) reviewed the titles and abstracts of all 2822 articles. A third author (SK) resolved any discrepancies. Following this step, two authors (CM and HMB) reviewed the full text of all 114 articles eligible for full-text screening. A third author (SK) resolved any discrepancies. Eighty articles were excluded for the following reasons: they did not have data on the



**Figure 1** Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram.

specified outcomes ( $n=27$ ), used qualitative methodologies ( $n=27$ ), focused on a tobacco product other than e-cigarettes ( $n=12$ ), were only focused on menthol flavour ( $n=2$ ), was a duplicate ( $n=1$ ) or were not peer-reviewed, did not include original data, did not include full-text or included only a conference abstract ( $n=11$ ). Articles that addressed e-cigarettes from the original systematic review ( $n=17$ ) were then added to the 34 articles identified from this current review, combining for a total of 51 articles included in the final analysis. The study selection processes, which approximate but do not exactly follow the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology, are illustrated in figure 1.<sup>23</sup>

### Data extraction and synthesis

For the articles identified in the most current review, three authors (CM, HMB, SK) independently extracted data using a data extraction sheet, which assessed study aim, type of flavoured tobacco product, characteristics of study populations and study design, and main results and findings related to the impact of flavours in tobacco products. We used a validated quality assessment tool (QATSDD) to examine the quality of quantitative studies with a diverse range of research designs.<sup>24</sup> Studies were scored on a 4-point scale from 0 (did not address criteria at all) to 3 (completely addressed criteria), with specified guidance to inform scorers based on the level of detail provided by study authors.<sup>24</sup> Specific scores were not used for inclusion/exclusion or used in any analysis. Rather, the tool was used to provide a valuable overall assessment of the general quality of included studies from which our conclusions are based. To ensure agreement in data

extraction and quality assessment, three authors (CM, HMB, SK) reviewed and extracted the same three articles, then compared results of review and extraction, resolving discrepancies through an iterative approach of discussion. Once mutual standards were decided upon based on this process, each of the three authors then split up the remainder of articles to extract and assess on their own. We created evidence tables using pertinent information extracted from each study, and we grouped the results by outcome measures. A similar procedure was conducted in the previous review, and all data were combined for final data analysis. A meta-analysis was not conducted due to the heterogeneity in outcomes across studies.

### Patient and public involvement

This research did not include input from patients or the public.

### RESULTS

The review included 51 final articles for synthesis, including 17 published up to 2016 and 34 published between 2016 and 2018. Most studies included adults only ( $n=30$ ), though 13 included youth and 8 included both youth and adults (table 1).

Results of this review are broken out into three age categories: youth, adults, and youth and adults combined. Studies defined these age groups differently, and we therefore used the age groups as defined by the study authors. Most youth were defined as anyone below age 18 years (though some went up to age 19 years<sup>25</sup>), and most adults were defined as 18+ years. Additionally, though young adults are an important population and were included as

**Table 1** Characteristics of included studies (n=51)

Sample characteristics		N (%)	US studies (n=37), N (%)	International studies (n=14), N (%)
Population	Youth only	13 (25)	9 (24)	4 (29)
	Adults only	30 (59)	22 (59)	8 (57)
	Both youth and adults	8 (16)	6 (16)	2 (14)
Design	Cross-sectional	47 (92)	33 (89)	14 (100)
	Longitudinal	4 (8)	4 (11)	0 (0)
Sampling (not mutually exclusive)	Convenience	35 (69)	23 (62)	12 (86)
	Probability	19 (37)	17 (46)	2 (14)
Outcome measure (not mutually exclusive)	Taste, appeal, perceived risk	14 (27)	10 (27)	4 (29)
	Reasons for use	13 (25)	11 (30)	2 (14)
	Susceptibility, intention to try/ initiation	17 (33)	11 (30)	6 (43)
	Preference	9 (18)	7 (19)	2 (14)
	Current use behaviours	12 (24)	10 (27)	2 (14)
	Quit intention/quitting behaviour	10 (20)	7 (19)	3 (21)

a separate age group in some studies in the review, the variability in definitions of this age group made it difficult to separate for purposes of the results (some defining as ages 19–34 years, some as ages 18–29 years, etc), and we therefore included all young adults in the adult category. Specific age groups used by authors can be found in [table 2](#).

Seventy-two per cent (n=37) of included studies were conducted in the USA. While four studies used longitudinal designs, most (n=47; 92%) were cross-sectional. Study populations, aims and relevant outcomes are provided in [table 2](#), with more detailed descriptions of analytical methods and results included in online supplementary table 1.

### Taste, appeal and risk perceptions

#### Youth

Four studies surveyed probability samples of youth and assessed harm perceptions of e-cigarettes, all observing similar results. Three studies of youth in the USA (two national samples and one state-wide sample) and one national sample of youth in the UK found that perceptions of e-cigarette harm differed depending on the product flavouring. Specifically, fruit and candy-flavoured e-cigarettes were perceived as less harmful than tobacco-flavoured e-cigarettes,<sup>26 27</sup> and ever or current e-cigarette users were less likely than non-users to perceive flavoured e-cigarettes or tobacco as harmful.<sup>28 29</sup>

#### Adults

Eight studies were conducted among adults, including three laboratory experiments and one discrete choice experiment that examined the effect of e-cigarette flavours on factors such as ratings of taste and appeal.<sup>30–33</sup> Four studies included relatively small convenience

samples of adults, each finding similar results: flavours in e-cigarettes enhanced the rewarding and reinforcing value of e-cigarettes compared with unflavoured e-cigarettes,<sup>30</sup> and the appealing sensory characteristics of flavours (ie, sweetness and coolness) were positively associated with liking of the product,<sup>32 33</sup> the willingness to use again and an increase in amount willing to pay for the product.<sup>31 32</sup> Similarly, in a cross-sectional survey of 765 current or former adult smokers, removal of flavours significantly reduced the price respondents were willing to pay for e-cigarettes, though this association was not observed among dual users of cigarettes and e-cigarettes.<sup>34</sup> One study in the USA and two international studies likewise found that among ever or current e-cigarette users, the taste and variety of flavours were positive features of e-cigarettes and contributed to increased enjoyment of the product.<sup>35–37</sup>

#### Youth and adults

Two studies examined appeal and harm perceptions in convenience samples of youth and adults. A sample of 216 youth and 432 adults in the USA found that adult smokers rated interest toward e-cigarettes significantly higher than non-smoking teens for each e-cigarette flavour examined (note: study was funded by an e-cigarette company).<sup>38</sup> One discrete choice experiment in Canada (n=915) found that e-cigarette flavour significantly predicted lower perceptions of product harm; specifically, in the overall sample, menthol and coffee flavours were perceived as less harmful; among younger non-smokers, coffee flavour was perceived as less harmful, while younger smokers perceived cherry flavour as less harmful and older smokers perceived tobacco flavour as less harmful.<sup>39</sup>

**Table 2** Sample characteristics and objectives of included articles (\* indicates study was included in original 2016 review)

Study ID (country)	Sample size and study population	Study aim	Main findings on flavours' impact
Amato <i>et al</i> (USA) <sup>42</sup>	n=9301 Adults (18+ years) Tobacco users and non-users	Investigate patterns of e-cigarettes' use in order to establish a standard definition of e-cigarette current use prevalence for the purpose of population surveillance.	Current e-cigarette users cited flavours as a reason for use more often than past users.
Audrain-McGovern <i>et al</i> (USA) <sup>30</sup>	n=32 Young adults (18–30 years) Current cigarette smokers and had ever used an e-cigarette	Determine whether flavouring enhances the subjective rewarding value, relative reinforcing value and absolute reinforcing value of an e-cigarette with nicotine compared with an unflavoured e-cigarette with nicotine.	E-cigarette flavouring enhanced the rewarding and reinforcing value of e-cigarettes with nicotine compared with unflavoured e-cigarettes with nicotine.
Barnes <i>et al</i> (USA) <sup>31</sup>	n=36 Adults (18+ years) Current cigarette smokers naive to e-cigarettes	Examine e-cigarettes' abuse liability compared with conventional tobacco cigarettes that varied in e-cigarette flavour and modified-risk message.	Cherry flavour increased abuse liability relative to unflavoured e-cigarettes (ie, increased the degree to which e-cigarettes led to physical/psychological dependence).
Berg (USA) <sup>46</sup>	n=1567 Young adults (18–34 years) E-cigarette users, non-users; cigarette users, non-users	Compare (1) e-cigarette never, current and former users; (2) never, current and former traditional cigarette smokers in relation to e-cigarette use characteristics, flavours preferred and reasons for use and (3) reasons for discontinued use among former e-cigarette users across never, current and former smokers.	Flavours were frequently indicated as reason for use across smoking and non-smoking e-cigarette users
Bold <i>et al</i> (USA) <sup>53</sup>	n=340 Youth (middle school and high school students) Ever e-cigarette users	Investigate whether certain reasons for trying e-cigarettes would predict continued use over time.	Good flavours were highly endorsed by youth as a reason for trying e-cigarettes; in univariate models, endorsing good flavours as a reason for trying e-cigarettes predicted continued e-cigarette use and e-cigarette frequency, but was no longer a significant predictor after adjusting for other covariates including cigarette smoking status.
Brozek <i>et al</i> (Poland) <sup>56</sup>	n=46 Adults (18–35 years) E-cigarette users	Assess prevalence of e-cigarette and tobacco cigarette use; to compare the patterns of smoking and to assess the attitudes and motivations for e-cigarette use.	More than one-fourth of e-cigarette users started using e-cigarettes because of the unique flavours.
Buckell <i>et al</i> (USA) <sup>66</sup>	n=2031 Adults (18–64 years) Current cigarette smokers or recent quitters	Estimate preferences for flavours in cigarettes and e-cigarettes while controlling for other attributes of both products, and study how these preferences vary with individual characteristics.	Among e-cigarette flavours, adult smokers preferred tobacco flavour over fruit/sweet and menthol flavours; younger adult smokers, those with a higher education and those with a recent quit attempt prefer all flavours of e-cigarettes compared with tobacco cigarettes.
Camenga <i>et al</i> (USA) <sup>75</sup>	n=189 Youth (14–18 years) and young adults (18–24 years) Lifetime cigarette smokers and ever e-cigarette users	Examine the prevalence and predictors of current and former smokers' use of e-cigarettes for smoking cessation.	Preference for using a combination of two or more e-cigarette flavours mixed together was associated with increased odds of using e-cigarettes for smoking cessation, relative to e-cigarette users without a preferred flavour.
Chen <i>et al</i> (USA) <sup>54</sup>	n=18392 Youth (11–18 years) Non-smokers	Explore association between e-cigarette use and smoking susceptibility among non-smoking youth.	Flavoured e-cigarette use was associated with increased smoking susceptibility among non-smoking youth, particularly among females and those not susceptible to tobacco marketing.

Continued

Table 2 Continued

Study ID (country)	Sample size and study population	Study aim	Main findings on flavours' impact
Chen (USA) <sup>35</sup>	n=4645 Young adults (18–34 years) Current cigarette smokers at Wave 1	Examine differences in smoking reduction and cessation among young adult smokers who did not use e-cigarettes, who used e-cigarettes with tobacco and menthol/mint flavours and who used e-cigarettes with one or multiple non-tobacco and non-menthol flavours.	Compared with non-e-cigarette users, users of non-tobacco/menthol e-cigarette flavours were more likely to have reduced or quit smoking cigarettes in the past year; current e-cigarette users highly endorsed using e-cigarettes because of appealing flavours, with those endorsing this reason for use more than twice as likely to have reduced or quit smoking in the past year than e-cigarette users who did not endorse this reason for use.
Clarke and Lusher (UK) <sup>25</sup>	n=256 Youth (16–19 years) Tobacco users and non-users	Investigate factors that lead to willingness to try e-cigarettes among UK youth.	Youth reported a preference for non-tobacco-flavoured e-cigarettes, regardless of smoking status; youth with a more positive prototype of smokers were more willing to try flavoured e-cigarettes, while youth with a more negative prototype of e-cigarette users were less willing to try flavoured e-cigarettes.
Coleman <i>et al</i> (USA) <sup>43</sup>	n=3373 Adults (18+ years) Current e-cigarette users	Examine patterns of current e-cigarette use among daily and non-daily adult users.	Appealing flavours were highly cited as a reason for e-cigarette use, particularly among never smokers; more frequent e-cigarette users (daily vs moderate or infrequent) were more likely to initiate with a non-tobacco-flavoured e-cigarette.
Cooper <i>et al</i> (USA) <sup>28</sup>	n=3704 Youth (grades 6, 8 and 10) Tobacco users and non-users	Evaluate harm perceptions and perceived addictiveness of e-cigarettes among youth.	Youth who were ever or current e-cigarette users had higher odds of reporting flavoured e-cigarettes as less harmful than non-e-cigarette users.
Czoli <i>et al</i> (Canada) <sup>39</sup>	n=915 Youth and young adults (16–24 years) and adults (25+ years) Users and non-users (youth and young adults) and users (adults)	Determine the effect of distinct attributes of e-cigarettes (flavours, nicotine content, health warnings, price) and attribute levels on consumer choice.	Flavours in e-cigarettes significantly predicted lower perceptions of product harm and ability to help someone quit smoking.
Dai and Hao (USA) <sup>29</sup>	n=21 491 Youth (middle and high school students) Tobacco users and non-users	Examine the (1) association between flavoured e-cigarette use and intention to initiate cigarette smoking among never-smoking youth, (2) association between flavoured e-cigarette use and intention to quit tobacco use in the next 12 months among current youth smokers and (3) association between flavoured e-cigarette use and youth perception of the danger of tobacco.	Compared with not using e-cigarettes, flavoured e-cigarette use was associated lower perceived harm of tobacco, higher intention to initiate cigarette use among never smoking youth and lower quit intentions among current smoking youth.
Elkalmi <i>et al</i> (Malaysia) <sup>36</sup>	n=277 Primarily adults (18+ years) but 7.2% of sample was 17 years or younger Tobacco users and non-users	Determine the prevalence of current e-cigarette use and identify sociodemographic factors, motivators, attitudes and perceptions that are associated with current e-cigarette use.	The majority of respondents who had tried e-cigarettes reported that the variety of flavours contributed to more enjoyment of the product compared with conventional cigarettes.
Etter (France, Belgium and other countries) <sup>37</sup>	n=81 Adults (18+ years) Current e-cigarette users	Assess usage patterns of e-cigarettes, reasons for use and users' opinions of these products.	Adult e-cigarette users reported flavours as being the most positive feature of the product.
Etter (France, USA, Switzerland, UK and other countries) <sup>72</sup>	n=1685 Adults (18+ years) Current e-cigarette users	Describe personal characteristics of vapers, their utilisation patterns, any modifications of the devices and compare users of prefilled cartridges, refillable tanks, and modified models for their patterns of use, reasons for use, satisfaction and perceived effects on smoking.	Tobacco flavour was reported to be the most preferred e-cigarette flavour among current users, particularly among those who had recently started vaping; most respondents reported that flavours helped them to either quit smoking or reduce their smoking consumption.

Continued

Table 2 Continued

Study ID (country)	Sample size and study population	Study aim	Main findings on flavours' impact
Farsalinos <i>et al</i> (online survey in 10 languages) <sup>71</sup>	n=4618 Adults (18+ years) E-cigarette users	Examine the patterns and perceptions of flavouring use in e-cigarettes among dedicated users.	E-cigarette users who were former smokers were more likely to prefer fruit and sweet flavours compared with current smokers. E-cigarette users reported that the variability of e-cigarette flavours is an important factor in reducing or quitting cigarette smoking and a greater number of flavours used was associated with smoking abstinence.
Farsalinos <i>et al</i> (online survey in 10 languages) <sup>58</sup>	n=19441 Adults (18+ years) E-cigarette users	Assess the characteristics and experiences of a large, worldwide sample of e-cigarette users and examine the differences between those who partially and completely substituted smoking with e-cigarette use.	The variability of flavours was cited as one of the reasons for initiating e-cigarette use, though it was not a primary reason.
Ford <i>et al</i> (UK) <sup>26</sup>	n=1205 Youth (11–16 years) Tobacco users and non-users	Examine adolescents' awareness of e-cigarette marketing and investigate the impact of e-cigarette flavour descriptors on perceptions of product harm and user image.	Fruit and sweet flavours were perceived as more likely to be tried by young never smokers than adult smokers trying to quit. The perceived harmfulness of e-cigarettes was moderated by product flavours.
Goldenson <i>et al</i> (USA) <sup>32</sup>	n=20 Young adults (19–34 years) Current e-cigarette users	Assess whether sweet flavourings and nicotine affect e-cigarette appeal; sweet flavourings increase perceived sweetness; nicotine increases throat hit; and perceived sweetness and throat hit are associated with appeal.	Sweet-flavoured e-cigarette solutions increased appeal (including liking, willingness to use again and amount willing to pay) and perceived sweetness ratings.
Gubner <i>et al</i> (USA) <sup>45</sup>	n=168 Adults (18+ years) Weekly or daily e-cigarette users	Examine e-cigarette use by individuals in treatment for substance abuse.	A large proportion of daily and weekly e-cigarette users reported using e-cigarettes because they have good flavours; daily e-cigarette users were more likely to use more types of flavours compared with weekly users.
Harrell <i>et al</i> (USA) <sup>50</sup>	n=3907 youth, n=5482 young adults and n=6051 adults Youth (12–17 years), young adults (18–29 years) and adults (30+ years) Tobacco users and non-users	Investigate whether the use of flavoured e-cigarettes varies between youth, young adults and adults.	Initiation with and current use of flavoured e-cigarettes were higher among youth and young adults compared with older adults, and citing flavour availability as a reason for use was higher among youth current users relative to young adults and older adults.
Harrell <i>et al</i> (USA) <sup>69</sup>	n=143 youth and n=1325 young adults Youth (12–17 years) and young adults (18–29 years) Current tobacco product users	Determine the potential for reductions in the prevalence of young people's e-cigarette and tobacco use if characterising flavours were not present.	The large majority of youth and young adult current tobacco users reported use of flavoured e-cigarettes, and about three-fourths of flavoured e-cigarette users reported they would no longer use the product if it was not flavoured.
Kim <i>et al</i> (USA) <sup>33</sup>	n=31 Adults (18+ years) Current e-cigarette users	Examine the extent to which the perception of sweet and other flavours is associated with liking and disliking of flavoured e-cigarettes.	Flavours influenced hedonic ratings of e-cigarettes, such that, in general, sweetness and coolness were positively associated with liking while bitterness and harshness were negatively associated with liking of e-cigarettes.
Kinouani <i>et al</i> (France) <sup>57</sup>	n=1086 University students (18+ years; more than 90% 18–24 years) Ever e-cigarette users	Describe the relationship between e-cigarette use and tobacco smoking and describe reasons for experimenting with e-cigarettes.	The third most cited reason for trying e-cigarettes was because of attractive flavours, behind reasons of curiosity and offered to try by someone.

Continued

Table 2 Continued

Study ID (country)	Sample size and study population	Study aim	Main findings on flavours' impact
Kong <i>et al</i> (USA) <sup>62</sup>	n=1157 Youth and young adults E-cigarette users	Assess reasons for e-cigarette experimentation and discontinuation and examine whether these reasons differed by school level (MS, HS, college) and cigarette smoking status.	Availability of flavours was a primary reason for experimentation with e-cigarettes and appealing flavours were particularly important to high school students.
Krishnan-Sarin <i>et al</i> (USA) <sup>64</sup>	n=4780 Youth (middle school and high school students) Tobacco users and non-users	Examine e-cigarette awareness, use patterns, susceptibility to future use, preferences, product components used, and sources of marketing and access among youth.	Use and preference for sweet e-cigarette flavours were high among adolescents regardless of cigarette smoking status.
Lee <i>et al</i> (USA) <sup>60</sup>	n=1185 Young adults (18–25 years) Tobacco users and non-users	Investigate the characteristics of potential and current e-cigarette users based on four different levels of use acceptability and determinants that promote e-cigarette acceptability.	A higher preference for the availability of flavours in e-cigarettes was associated with experimentation and current use of e-cigarettes among college students.
Lee <i>et al</i> (South Korea) <sup>40</sup>	n=6656 Youth (13–18 years) Ever e-cigarette users	Determine the relation between frequency of e-cigarette use and the frequency and intensity of conventional cigarette smoking; and identify the association between reasons for e-cigarette use and frequency of use.	Nearly 1 in 10 youth cited good flavours as the main reason for using e-cigarettes, though this reason ranked behind five others, including curiosity and potentially being less harmful.
Litt <i>et al</i> (USA) <sup>70</sup>	n=88 Adults (18–55 years) Cigarette smokers	Examine the influence of flavouring on the smoking and vaping behaviour of cigarette smokers asked to adopt e-cigarettes for 6 weeks.	Cigarette smoking frequency was most reduced in participants assigned to menthol-flavoured e-cigarettes, while it was least reduced in those assigned to cherry and chocolate flavours; participants assigned to tobacco-flavoured e-cigarettes had the highest rates of vaping, while those assigned to chocolate had the lowest rates of vaping.
Maglalang <i>et al</i> (USA) <sup>47</sup>	n=56 Asian American and Pacific Islander young adults (18–25 years) Current e-cigarette users	Characterise e-cigarette use and risk perceptions among Asian American and Pacific Islander young adults in California.	Fruit and candy/sweet flavours were most preferred by current e-cigarette users, though citing flavours as a reason for using e-cigarettes was reported by a low percentage of respondents, behind a variety of other reasons.
Morean <i>et al</i> (USA) <sup>88</sup>	n=396 adolescents and n=590 adults Adolescents (high school students) and adults (18+ years) Past-month e-cigarette users	Examine differences in adolescents' and adults' preferences for e-liquid flavours and whether their preferences or the total number of flavours preferred were associated with number of days of e-cigarette use in the past month.	Compared with adults, adolescents were more likely to prefer e-liquid flavours such as fruit, candy/dessert and vanilla, while adults were more likely to prefer tobacco, menthol/mint, coffee and spice flavours. Among adolescents (though not adults), preferences for particular e-liquid flavours (ie, fruit, dessert or alcohol flavoured) and the total number of flavours preferred were associated with more frequent e-cigarette use.
Nonnemaker <i>et al</i> (USA) <sup>34</sup>	n=765 Adults (18+ years) Current or former smokers	Examines how e-cigarette attributes influence willingness to pay for e-cigarettes.	Losing flavours significantly reduced the price participants are willing to pay for e-cigarettes, though this relationship was not found for dual users of cigarettes and e-cigarettes.
Patel <i>et al</i> (USA) <sup>48</sup>	n=2448 Adults (18+ years) Current e-cigarette users	Assess reasons for e-cigarette use among current e-cigarette users.	Reasons for e-cigarette use among current adult users varied by sociodemographic and user characteristics; notably, flavourings were more likely to be cited as a reason for use among younger age groups (ages 18–24, 25–34 and 35–54 years).

Continued



Table 2 Continued

Study ID (country)	Sample size and study population	Study aim	Main findings on flavours' impact
Pepper <i>et al</i> (USA) <sup>52</sup>	n=228 Youth (11–19 years), males Tobacco users and non-users	Sought to understand awareness of and willingness to try e-cigarettes among adolescent males.	Flavoured e-cigarettes did not increase male adolescents' willingness to try e-cigarettes compared with plain varieties.
Pepper <i>et al</i> (USA) <sup>59</sup>	n=3878 Adults (18+ years) Tobacco users and non-users	Explore reasons for starting and then stopping e-cigarettes use and examine differences in discontinuation by reason for trying among population-based sample of US adults.	Few adult e-cigarette users reported starting e-cigarette use because of the available flavours.
Pepper <i>et al</i> (USA) <sup>27</sup>	n=1125 Youth (13–17 years) Tobacco users and non-users	Examine the impact of flavour on interest in trying e-cigarettes and harm beliefs.	Adolescents were more interested in trying menthol, candy or fruit-flavoured e-cigarettes than tobacco or alcohol flavours; belief that these particular flavours were less harmful than tobacco or alcohol flavours partly mediated this relationship.
Pesko <i>et al</i> (USA) <sup>67</sup>	n=1020 Adults (18+ years) Current cigarette smokers	Determine the preferences and relative importance placed on e-cigarette warning labels, flavour regulation and prices.	Restriction of flavour availability in e-cigarettes to tobacco and menthol was associated with a significant reduction in e-cigarette selection, particularly among young adults compared with older adults.
Russell <i>et al</i> (USA) <sup>61</sup>	n=20836 Adults (18+ years) Frequent e-cigarette users	Examine flavour preferences of frequent e-cigarette users.	Adults are increasingly initiating e-cigarette use with non-tobacco flavours, particularly fruit and dessert flavours; never smoker e-cigarette users were more likely to initiate with and currently use fruit/fruit beverage-flavoured e-cigarettes compared with switchers, dual users and former smoker e-cigarette users.
Rutten <i>et al</i> (USA) <sup>49</sup>	n=582 Adults (18+ years) Current dual users of cigarettes and e-cigarettes	Assess attitudes, beliefs and behaviours relating to e-cigarette use among current cigarette smokers.	Dual users of cigarettes and e-cigarettes ranked appealing flavours relatively low on the list of reasons for using e-cigarettes; no differences in smoking quit intentions or reduction in the use of cigarettes was observed for those reporting using e-cigarettes because of flavours compared with those not reporting using e-cigarettes because of the flavours.
Shang <i>et al</i> (USA) <sup>63</sup>	n=515 Youth (14–17 years) Tobacco users and non-users	Understand how different attributes (flavours, health warnings, device types) influence youth's decisions to choose e-cigarettes.	Among youth ever and never e-cigarette users, fruit/sweet/beverage flavours increased the probability that a youth chose an e-cigarette product.
Shiffman <i>et al</i> (USA) <sup>38</sup>	n=216 (youth) and n=432 (adults) Youth (13–17 years) Adults (19–80 years) Non-users (youth) and users (adult)	Compare e-cigarettes interest between nonsmoking teens and adult smoker, across flavours and assess differences in flavour preferences among adult smokers based on e-cigarettes use history.	The interest of non-smoking teens in trying flavoured e-cigarettes was very low, and interest was not influenced by flavour descriptors. Though adult smokers' interest was also modest, their interest was significantly higher than that of non-smoking teens for each flavour.
Shiplo <i>et al</i> (Canada) <sup>51</sup>	n=1095 Youth and young adults (16–24 years) Adults (25+ years) Non-smokers and smokers (youth and young adults) and smokers (adults)	Examines e-cigarette ever and current use, types of products used and reasons for use.	Use of flavoured e-cigarettes varies by smoking status, with smokers being more likely to try flavours than non-smokers. A common reason for e-cigarette use is for the taste.

Continued

Table 2 Continued

Study ID (country)	Sample size and study population	Study aim	Main findings on flavours' impact
Spears <i>et al</i> (USA) <sup>44</sup>	n=550 Adults (18+ years) Current e-cigarette users	Examine reasons for e-cigarette use and related risk perceptions among individuals with and without mental health conditions.	Compared with former smokers without mental health conditions, former smokers with mental health conditions placed higher importance on appealing flavours as a reason for e-cigarette.
Tackett <i>et al</i> (USA) <sup>74</sup>	n=215 Adults (18+ years) E-cigarette users	Estimate e-cigarettes preference, e-cigarettes use behaviours, perceived harm and health beliefs of various smoking cessation medications, nicotine replacement therapies and nicotine/tobacco products, and smoking history and current biochemically verified smoking status.	Most e-cigarette users reported a preference for vaping non-traditional flavours. Those who reported vaping non-tobacco and non-menthol flavours were more likely to have quit smoking compared with those who vaped traditional (tobacco/menthol) flavours.
Tsai <i>et al</i> (USA) <sup>41</sup>	n=4049 Youth (grades 6–12) Ever e-cigarette users	Assess self-reported reasons for e-cigarette use among middle school and high school student e-cigarette users.	One of the primary reasons for e-cigarette use by middle school and high school students was the availability of flavours, particularly among high school students.
Vasiljevic <i>et al</i> (UK) <sup>55</sup>	n=471 Youth (11–16 years) Non-e-cigarette users	Assess the impact on appeal of tobacco smoking after exposure to advertisements for e-cigarettes with and without candy-like flavours.	Flavoured, compared with non-flavoured, e-cigarette advertisements elicited greater interest in buying and trying e-cigarettes.
Weaver <i>et al</i> (USA) <sup>73</sup>	n=858 Adults (18+ years) Current cigarette smokers	Assess the effect of 'real world' e-cigarette use on population quit rates of adult smokers, accounting for frequency of use, device type, e-liquid flavour and reasons for use.	Compared with non-e-cigarette users, users of menthol/wintergreen/mint or other non-tobacco/menthol flavour e-cigarettes (eg, fruit, dessert, spice) were more likely to report a quit attempt, but users of other non-tobacco/menthol e-cigarette flavours had significantly lower odds of quitting smoking than non-users of e-cigarettes in the past year.
Yingst <i>et al</i> (USA and other countries) <sup>65</sup>	n=421 (87% in USA; 13% outside USA) Adults (18+ years) E-cigarette users	Examine the frequency with which e-cigarette users transition between device types and identify device characteristics and user preferences that may influence such transitions.	Most e-cigarette users began use with a device shaped like a cigarette (first-generation devices) and transitioned to a larger advanced generation device with a more powerful battery and a wider choice of liquid flavours. Advanced generation device e-cigarette users report the variety of flavours as being important characteristic of e-cigarettes.

## Reasons for use

### Youth

Two national probability samples of youth examining reasons for e-cigarette use found varied results. Less than 10% of South Korean youth who ever used e-cigarettes reported using the product because of good flavours,<sup>40</sup> compared with roughly a third of US students reporting ever using e-cigarettes because of the availability of flavours, with high school students more likely than middle school students to report flavours as a reason for use.<sup>41</sup>

### Adults

Nine studies in the USA examined reasons for using e-cigarettes among adults, also finding varied results. Three probability samples (two national and one state-wide) found that a majority of current e-cigarette users cited appealing flavours as a reason for using e-cigarettes,<sup>35 42</sup> particularly among never cigarette smokers compared with current and former smokers.<sup>43</sup> Another national probability sample in the USA (n=550) found that former smokers with mental health conditions placed a higher importance on appealing flavours as a reason for use compared with former smokers without mental health conditions.<sup>44</sup> Further, about 40% of daily and weekly e-cigarette users (n=168) at substance use treatment centres reported good flavours as a reason for using e-cigarettes.<sup>45</sup> Among a convenience sample of 1567 young adults, roughly a third of those who were non-e-cigarette users reported appealing flavours as a reason for possible e-cigarette use in the future, while a majority of current e-cigarette users reported appealing flavours and the ability to experiment with a variety of flavours as reasons for use.<sup>46</sup> Three other studies in the USA (two national probability samples and one small convenience sample) observed relatively low proportions of current adult e-cigarette users reporting using e-cigarettes because of product flavourings, behind a variety of other reasons for use,<sup>47–49</sup> though flavours were more likely to be cited as a reason for use among younger age groups, particularly young adults aged 18–24 years, and among users of tank devices compared with disposables.<sup>48</sup>

### Youth and adults

Two studies in the USA and Canada among youth and adults found that citing flavour availability or taste as a reason for e-cigarette use was higher among younger e-cigarette users compared with older users.<sup>50 51</sup>

## Susceptibility, intention to try and initiation

### Youth

Seven studies in the USA and the UK examined susceptibility, intention to try or initiation of e-cigarettes among youth. One study of a national probability sample of 228 adolescent males in the USA found no differences in willingness to try flavoured e-cigarettes compared with plain e-cigarettes.<sup>52</sup> However, the other six studies reported positive associations between flavours and e-cigarette

use intentions. In a convenience sample of 340 youth in the USA who were ever e-cigarette users, more than 40% endorsed good flavours as a reason for first trying e-cigarettes, the second highest endorsed reason.<sup>53</sup> Similarly, in a convenience sample of 256 UK youth, cigarette smokers and non-smokers were more willing to try flavoured e-cigarettes than tobacco-flavoured e-cigarettes (90% vs 73% and 34% vs 12%, respectively); further, having a positive prototype of smokers was associated with increased willingness to try flavoured e-cigarettes.<sup>25</sup> Three different studies using national probability samples of US youth found similar relationships between flavours and e-cigarette use susceptibility and intentions to use. Adolescents were more likely to try menthol-flavoured, candy-flavoured or fruit-flavoured e-cigarettes compared with tobacco-flavoured e-cigarettes<sup>27</sup>; and flavoured e-cigarette use among non-smoking youth was associated with increased intention to initiate cigarette use<sup>29</sup> and smoking susceptibility, particularly among females and those not susceptible to tobacco marketing.<sup>54</sup> Finally, a convenience sample of 471 non-e-cigarette using youth in the UK found that exposure to flavoured e-cigarette ads, compared with non-flavoured e-cigarette ads, increased interest in buying and trying e-cigarettes.<sup>55</sup>

### Adults

Six studies conducted in the USA and internationally examined intention to try or initiation of e-cigarettes among adults. Two studies using convenience samples of young adults in Poland (n=46) and France (n=1086) both found that roughly 25%–30% of e-cigarette users tried or started using e-cigarettes because of the variability of flavours, though other reasons for initiation were rated more highly than flavours.<sup>56 57</sup> Similarly, among an online convenience sample of international e-cigarette users (n=19 441) (note: study was funded by an e-cigarette advocacy group) and among a combined probability and non-probability sample of US adults (n=3878), the availability of appealing flavours was not frequently cited as a reason for e-cigarette initiation.<sup>58 59</sup> However, two convenience samples of US adults found that the availability of flavours in e-cigarettes was associated with increased intention to use the product among young adult college students,<sup>60</sup> and never smoker e-cigarette users were more likely to have initiated e-cigarette use with a fruit-flavoured product compared with switchers (from regular cigarette smoking to regular e-cigarette use), dual users and former smoker e-cigarette users.<sup>61</sup>

### Youth and adults

Four studies examined interest in trying and initiation of e-cigarettes among youth and adults. One study of 648 youth and adults in the USA observed that adult smokers' interest in trying e-cigarettes was significantly higher than non-smoking teens' interest for all 15 e-cigarette flavours investigated (note: study was funded by an e-cigarette company).<sup>38</sup> However, the three other studies conducted found similar results, in that youth and younger adults

in Canada expressed more interest in trying non-tobacco-flavoured e-cigarettes than older adults<sup>39</sup>; high school students in the USA were more likely to experiment with e-cigarettes because of flavours compared with college students, with 40% of the overall sample (n=1157) reporting the availability of flavours as a reason for experimentation with e-cigarettes<sup>62</sup>; and youth and young adults reported higher initiation with flavoured e-cigarette use compared with tobacco-flavoured e-cigarettes.<sup>50</sup>

## Preference

### Youth

In three studies of youth, one discrete choice experiment of 515 e-cigarette ever and never users in the USA found that fruit, sweet and beverage flavours increased the probability (relative to tobacco flavour) of choosing an e-cigarette product.<sup>63</sup> A national probability sample of 1205 UK youth examined how youth perceive others to use e-cigarettes; youth perceived adult smokers who were trying to quit smoking as less likely to prefer cherry, candy floss or coffee flavoured e-cigarettes, whereas youth perceived adolescents their age to be more likely to try flavoured e-cigarettes compared with tobacco-flavoured.<sup>26</sup> Further, a convenience sample of 4780 middle school and high school students in the USA found that most ever e-cigarette users—regardless of cigarette smoking status—had tried and preferred sweet flavours compared with menthol and tobacco flavours.<sup>64</sup>

### Adults

Four studies examined preference among adults in relation to e-cigarette flavours. One international study of 421 e-cigarette users found that those using an advanced generation e-cigarette device were more likely to rate a variety of flavour choices as important, relative to users of first-generation devices.<sup>65</sup> A laboratory experiment of a small convenience sample of adults in the USA observed that ever e-cigarette users took twice as many puffs from flavoured e-cigarettes compared with unflavoured e-cigarettes.<sup>30</sup> Further, a discrete choice experiment of 2031 adults in the USA found that adult smokers preferred tobacco-flavoured e-cigarettes to fruit/sweet and menthol flavours,<sup>66</sup> while another discrete choice experiment of 1020 adults observed that increased flavour availability increased e-cigarette selection for younger cigarette smokers but not for older smokers.<sup>67</sup> Additionally, regardless of interest in quitting cigarettes, greater flavour availability increased e-cigarette selection.<sup>67</sup>

### Youth and adults

Two convenience samples of US youth and adults found that, compared with adult e-cigarette users, adolescent users were more likely to prefer e-cigarette flavours such as fruit and alcohol, while adults were more likely to prefer tobacco, menthol/mint, coffee and spice flavours; further, adult users preferred a greater number of e-cigarette flavours than adolescents.<sup>68</sup> Among 1468 youth and young adults currently using tobacco, most reported

use of flavoured e-cigarettes, and roughly three-quarters of those reported they would not use e-cigarettes if they were not available in a flavoured form, such as candy, fruit or mint/menthol.<sup>69</sup>

## Current use behaviours

### Youth

Two studies among US youth examined e-cigarette use behaviours. In a longitudinal study of 340 ever e-cigarette users, youth who initiated e-cigarette use because of good flavours were more frequent users of e-cigarettes, though this association was no longer significant after adjustment for other covariates.<sup>53</sup> Additionally, in a national probability sample of 18 395 never smoking youth, those who used e-cigarettes 3 or more days in the past 30 days were more likely to be flavoured e-cigarette users than those who had used e-cigarettes only 1 or 2 days in the past 30 days.<sup>54</sup>

### Adults

Eight studies among adults examined current e-cigarette use behaviours in relation to flavours. A two-phase longitudinal laboratory study of 88 current cigarette smokers in the USA assigned e-cigarettes to participants as substitution for cigarettes; the highest vaping rates were observed for those assigned to tobacco-flavoured e-cigarettes and the lowest rates were observed for those assigned to chocolate-flavoured.<sup>70</sup> A convenience sample of 168 e-cigarette users found that daily e-cigarette users reported using more types of flavours and were more likely to have used tobacco flavour or fruit/berry flavour compared with weekly users,<sup>45</sup> while a national probability sample of 4645 young adults in the USA found that users of non-tobacco/menthol flavours were more likely to vape daily compared with tobacco-/menthol-flavoured e-cigarette users.<sup>35</sup> Another national probability sample of 3373 current e-cigarette users in the USA found that daily e-cigarette users were more likely to have initiated with a non-tobacco-flavoured e-cigarette compared with moderate or infrequent e-cigarette users.<sup>43</sup> A convenience sample of 1185 college students in the USA found that a higher preference for the availability of flavours in e-cigarettes was associated with a higher likelihood of currently using e-cigarettes.<sup>60</sup> One international survey of 4618 e-cigarette users showed that users who were former smokers were more likely to prefer fruit and sweet flavours compared with current smokers (note: study was promoted by an e-cigarette advocacy group).<sup>71</sup> Another survey of 1685 e-cigarette users found that tobacco flavour was used by nearly half of the respondents who had started vaping the past 3 months compared with only a quarter of those who had been vaping for at least 4 months.<sup>72</sup> Lastly, a convenience sample of 20 836 frequent e-cigarette users in the USA found that the highest rate of current tobacco-flavoured e-cigarette use was reported by those who initiated e-cigarettes 5 or more years ago, while the lowest rate of tobacco-flavoured e-cigarette use was reported by those who initiated within the past year; those who initiated in

the past year had the highest rate of fruit, dessert and candy/sweet flavoured e-cigarette use, and never smoker e-cigarette users were more likely to use fruit-flavoured products and less likely to use tobacco-flavoured products compared with ever cigarette smokers.<sup>61</sup>

### Youth and adults

Two studies of youth and adults in the USA reported similar findings related to a preference for flavours among younger e-cigarette users. Nearly all youth and young adult current users (a probability and convenience sample in Texas and nationwide) reported a usual e-cigarette that was flavoured with something other than tobacco (97%–98%) compared with roughly 70% of older adults.<sup>50</sup> Similarly, a survey of 986 adolescents and adults in the USA found that adolescents who preferred to use fruit, dessert or alcohol-flavoured e-cigarettes reported using e-cigarettes more frequently, and preferring to use a greater number of flavours was associated with using the product more frequently in the past month, though these relationships were not seen among adult e-cigarette users.<sup>68</sup>

### Quit intentions and quitting behaviour

#### Youth

In regards to smoking cessation, one national probability sample of 21 491 youth in the USA found that among current smokers, students who reported using flavoured e-cigarettes were less likely to quit tobacco use compared with those who reported not using e-cigarettes or with those who had used non-flavoured e-cigarettes.<sup>29</sup>

#### Adults

Seven studies examined the relation between flavours in e-cigarettes and quit intentions and quitting behaviour among adults, finding varied results. One longitudinal study of 4645 young adult cigarette smokers in the USA found that e-cigarette users who used at least one non-tobacco/menthol flavour were more likely to have reduced or quit smoking cigarettes in the past year compared with non-e-cigarette users, and e-cigarette users who reported using e-cigarettes because of appealing flavours were more than twice as likely to have reduced or quit smoking compared with those who did not endorse using e-cigarettes for that reason.<sup>35</sup> Another longitudinal study of 858 cigarette smokers in the USA similarly found that users of non-tobacco flavour e-cigarettes (eg, fruit, dessert, spice) were more likely than non-e-cigarette users to report a quit attempt in the past 12 months; however, users of non-tobacco/menthol flavours were less likely to have quit smoking compared with non-e-cigarette users.<sup>73</sup> In a two-phase longitudinal laboratory study among 88 cigarette smokers, cigarette smoking frequency was most reduced in participants assigned to menthol-flavoured e-cigarettes, while it was least reduced in those assigned to cherry-flavoured or chocolate-flavoured e-cigarettes.<sup>70</sup> Two international surveys of current e-cigarette users both found that e-cigarette flavours were an important factor

in helping to reduce or quit cigarette smoking,<sup>71 72</sup> and the number of e-cigarette flavours used was associated with smoking abstinence (note: study was promoted by an e-cigarette advocacy group).<sup>71</sup> Further, a convenience sample of 215 e-cigarette users in the USA found that e-cigarette users reporting use of non-tobacco/menthol flavours were more likely to have quit smoking compared with those vaping tobacco/menthol flavours,<sup>74</sup> while a national probability sample of 582 dual users in the USA found no differences in smoking quit intentions or smoking reduction for those reporting using e-cigarette because of the flavours compared with e-cigarette users not endorsing use of e-cigarettes for that reason.<sup>49</sup>

### Youth and adults

Two studies among youth and adults examined quit intentions and behaviours. A discrete choice experiment of 915 Canadian tobacco users and non-users observed that menthol-flavoured and coffee-flavoured e-cigarettes were perceived as having a greater quit efficacy.<sup>39</sup> In a convenience sample of 189 youth and young adult ever e-cigarette users in the USA, preference for using a combination of at least two e-cigarette flavours mixed together was associated with increased likelihood of using e-cigarettes to quit smoking, relative to not having a preferred e-cigarette flavour.<sup>75</sup>

### Quality assessment

We used a validated quality assessment tool (QATSDD) to examine the quality of studies with a diverse range of research designs.<sup>24</sup> In this quality assessment tool, there are 14 criteria and each criterion is rated on a 4-point scale (0–3), with a maximum score of 42. Because the studies examined in this review use a variety of methodological approaches, the QATSDD tool was chosen as it was developed specifically for this purpose and has been shown to provide valid, reliable assessments of study quality.<sup>24</sup> Studies were scored on the criteria listed below, and all scores and criteria can be found in online supplementary table 2. Quality assessment scores relative to the maximum score possible ranged from 38% to 88% with a mean score of 66%. Nearly all studies sufficiently detailed their aims and objectives, the research setting, recruitment and data collection, the fit between their research question and method of data collection and analysis, justification for their analytical method, and the study strengths and limitations (see QATSDD scores in online supplementary table 2). However, few studies reported an explicit theoretical framework, user involvement in study design (eg, cognitive interviewing of survey measures), evidence of sample size consideration or statistical assessment of reliability and validity of measurement tools. A low score on these criteria do not necessarily mean that the study authors did not consider it (eg, power calculations that were not reported); rather, the criteria were not sufficiently described in the manuscript. Of note, three studies were funded or promoted by the e-cigarette industry or e-cigarette user advocacy groups.<sup>38 58 71</sup>



## DISCUSSION

Given the sharp increase in both the use of e-cigarettes (particularly among youth) and the amount of new research related to e-cigarettes and flavours published from 2016 to 2018 alone, this systematic review provides a necessary update of a previous review that included research on e-cigarettes and non-menthol flavours among youth and adults.<sup>4</sup> This synthesis of evidence regarding the role of non-menthol flavours in e-cigarettes on product perceptions and use is particularly relevant to the FDA's recently proposed policy framework that seeks to place additional regulations on the sale of non-menthol-flavoured e-cigarettes to youth.<sup>3</sup> Seventeen studies examining flavours in e-cigarettes were published up to 2016; from 2016 to 2018, 34 new studies were published, more than doubling the research in just 2 years.

This new review significantly expands earlier findings about e-cigarettes and flavour among youth and adults. The previous review showed initial evidence that flavours in e-cigarettes were primary reasons for willingness to try or use the products. This expanded systematic review includes emerging longitudinal data and adds evidence on the role of flavours in e-cigarettes among youth and adults. Among youth, flavours increase not only preferences for e-cigarettes but they also increase e-cigarette product appeal, willingness to use, susceptibility to use and initiation, as well as decrease e-cigarette product harm perceptions. Among adults, the expanded research now shows that e-cigarette flavours increase product appeal and enjoyment, and the availability of flavours is a primary reason for use for many adults. Further, our quality review process provides important insight for researchers in this field to improve the rigour of e-cigarette research and includes essential information on study sample size and the reliability or validity of measures.

Findings highlight the following: youth prefer non-tobacco-flavoured e-cigarettes<sup>63 64 68 69</sup>; flavours—particularly sweet flavours such as fruit and candy—decreased perceived product harm<sup>26–29 39</sup>; and the availability of appealing flavours is associated with an increased willingness to try e-cigarettes, initiation of e-cigarettes and susceptibility to cigarette smoking.<sup>25 27 29 53–55</sup> Findings specific to adults are more varied but demonstrate that non-menthol flavours in e-cigarettes increase appeal, enjoyment and the price users are willing to pay for the product<sup>30 32–37</sup> and are a primary reason many adults use e-cigarettes.<sup>35 42–46</sup> Evidence on whether non-menthol-flavoured e-cigarettes promote or disrupt cessation among adult smokers remains unclear.<sup>35 70–74</sup>

Given that non-menthol flavours available in e-cigarettes attract youth to use these products, the impetus for policymakers to address the issue is strong. Results from the current review make it clear that banning flavours in e-cigarettes would discourage youth use of these products; however, doing so may also discourage adult smokers from using e-cigarettes for smoking cessation.<sup>76</sup> It is also important to consider the context in which each of these studies was conducted; because this review included

results from both USA and global studies, policies may differ and individual cultural contexts around e-cigarette use may have affected the outcomes.

Policy action at the federal level regarding flavoured tobacco products has recently been undertaken, with the FDA seeking to limit the sale of non-menthol-flavoured e-cigarettes to age-restricted locations and heightening age verification practices for products sold online.<sup>3</sup> Also of note in that same announcement is FDA's consideration of banning menthol in cigarettes, which would significantly impact the tobacco control landscape.<sup>3</sup> FDA's recent proposed action appears to be affecting manufacturers; the tobacco company Altria recently announced that they would halt the sale of multiple e-cigarette products they produce, including flavoured products,<sup>77</sup> and Juul Labs also announced a suspension of its non-menthol-flavoured e-cigarettes in retail stores.<sup>78</sup> In the meantime, states and localities have the authority to restrict the sale of flavoured tobacco products, including flavoured e-cigarettes. A comprehensive review of flavoured e-cigarette regulations from 2017 showed that at the time, over 100 localities had implemented restrictions on the sale of flavoured e-cigarettes.<sup>79</sup> Movement has continued to be made on this topic since that review; for instance, San Francisco passed a measure to ban the sale of all flavoured tobacco products,<sup>80</sup> including e-cigarettes, in 2018. Jurisdictions globally have taken steps to more broadly regulate flavours in all tobacco products, recognising their impact on youth.<sup>17 81</sup> This is in accordance with the 2010 WHO Framework Convention on Tobacco Control guidelines that recommend restricting or banning flavours in all tobacco products.<sup>82</sup>

Based on the results of this review, it is important to consider deficits in the literature that would assist policymakers in developing the most impactful regulations. For one, it is important to note that the literature does not have a consistent and standardised way to categorise flavours. Yingst and colleagues<sup>83</sup> have attempted to identify such a classification system, which, if used by researchers, would allow results to be more easily compared across studies. This would also assist policymakers in regulating flavours more easily, as it is possible that some categories of flavours may be more appealing to youth than others. Similarly, because much of the research uses varying categories to examine age, it makes it difficult to disaggregate the effects flavours have on different age groups. Doing so would especially be helpful to policymakers who are trying to create regulations that would have the most impact on youth initiation while maintaining the potential for adult harm reduction, though more research is needed to explore the latter. Furthermore, use of the QATSDD tool reveals deficits in the existing literature. Few studies provided evidence of sample size consideration or commented on the reliability or validity of their measurement tools. Reviewing these types of parameters before publishing may ensure that researchers are providing the most rigorous explanation of their research as possible. Finally, since so few longitudinal studies are present, it

may be beneficial for researchers to use such data sets as PATH to show longitudinal trends in the outcomes presented in this review, in an effort to strengthen the existing body of literature with longitudinal data.

### Limitations

Our review is limited in several ways. First, relevant articles may have been missed due to the exclusion of grey literature, doctoral dissertations and non-English language articles; articles published within the search period (before March 2018) may also have been missed if they were not indexed in one of the searched databases by the time of the search. Similarly, we excluded qualitative articles in order to maintain consistency in data reviewed, though we recognise that qualitative data could potentially provide important contextual information on this topic. Second, a minimum threshold for study quality was not set, though only three studies received a score lower than 50% on the quality assessment (with scores of 48%, 45% and 38%), and the mean score of all studies was 66%. Further, three studies were funded or supported by the e-cigarette industry or user advocacy groups.<sup>38 58 71</sup> Findings from these studies, and studies scoring lower in study quality, should be interpreted with caution. Third, more than 90% of studies were cross-sectional in nature, preventing us from making causal inferences between flavours and the perceptions and use of flavoured e-cigarettes. Future research using longitudinal designs could further elucidate the role of flavours, particularly their effect on behavioural outcomes such as initiation among youth and cessation among adult smokers. Fourth, nearly half of all studies were conducted with convenience samples in the USA, limiting the generalisability of findings, though nearly 40% of all studies did use probability-based sampling. Lastly, as research on e-cigarette flavours continues to evolve and additional research is regularly published, periodic updates of this review will be needed.

### CONCLUSION

This systematic review provides a necessary update and extension of all evidence published to date on the role of flavours in e-cigarette perceptions and use behaviours. The increasing evidence among youth is clear: flavours in e-cigarettes (particularly sweet flavours) increase product appeal, decrease product harm perceptions and increase willingness to use and initiation of e-cigarettes. Similarly, findings among adults demonstrate that flavours increase product appeal and enjoyment, and the availability of flavours are a primary reason for use for many adults. As the role of e-cigarettes in smoking cessation—and particularly how flavours impact this relationship—remains unclear, longitudinal studies of adult smokers are needed to assess the effect that e-cigarettes may have promoting or disrupting efforts to reduce or quit cigarette use. Regardless, findings are clear that banning flavours in e-cigarettes would discourage youth use of these products.

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