



A Review of the Use and Appeal of Flavored Electronic Cigarettes

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Abstract

Purpose of Review E-cigarettes are available in a variety of flavors not found in traditional tobacco products (i.e., “nontraditional flavors”), which is a commonly cited reason for e-cigarette use. This review examines the prevalence of nontraditional-flavored e-cigarette use, mechanisms through which flavorings enhance product appeal, use of nontraditional-flavored e-cigarettes for smoking cessation, and differences in these findings between youth and adults.

Recent Findings Nontraditional-flavored e-cigarettes are used at e-cigarette initiation by the majority of youth. These flavors enhance the appeal of e-cigarettes by creating sensory perceptions of sweetness and coolness and masking the aversive taste of nicotine. Use of nontraditional-flavored e-cigarettes is higher among youth and young adults (vs. older adults) and among nonsmokers (vs. combustible cigarette smokers).

Summary Nontraditional-flavored e-cigarettes are popular among youth, but may be less common among older adults and combustible cigarette smokers. Further research is needed to determine whether use of e-cigarettes in nontraditional flavors affects smoking cessation.

Keywords Electronic cigarette · Vaping · Flavored · Flavor · Appeal

Introduction

Traditional tobacco products (e.g., combustible cigarettes, smokeless tobacco) were previously available in a variety of flavors that were disproportionately used in the initiation of tobacco product use among youth [1–6]. To combat this threat, regulatory agencies (e.g., U.S. Food and Drug Administration, European Parliament and the Council of the European Union) banned tobacco products with any characterizing flavors other than traditional tobacco flavor or menthol [7]. However, the prohibition of flavors in these products does not currently apply to new alternative tobacco products

such as electronic cigarettes (e-cigarettes) in the USA and in other countries across the world.

The growing popularity of e-cigarettes among youth [8] has raised concern over the public health impact of flavored e-cigarettes [9, 10]. E-cigarettes are available in a wide range of flavorings not found in combustible cigarettes [11]. E-cigarettes are currently the most commonly used tobacco product among US youth [8, 12], and the majority of youth report use of e-cigarettes in nontraditional flavors such as fruit or candy [13]. Adolescent e-cigarette users (vapers) cite the availability of e-cigarettes in these nontraditional flavors as a key reason for e-cigarette use [14]. Additionally, there is concern that use of nontraditional-flavored e-cigarettes could expose youth to aerosols containing compounds of known and unknown respiratory toxicity [15].

Since e-cigarettes do not involve the combustion of tobacco and are believed by experts to be less harmful than combustible cigarettes [16], they may have the potential to be a lower risk substitute and putative harm reduction measure for cigarette smokers [17–20]. Evidence from a recent clinical trial indicates that e-cigarettes may be more effective than nicotine-replacement therapies at helping smokers quit smoking [21], although earlier trials and observational studies are less conclusive [21–23]. Preliminary reports also indicate that the presence of flavorings could augment the

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effectiveness of e-cigarettes as smoking reduction or cessation aids by encouraging their use among smokers [24].

Effective tobacco control and regulatory policies require consideration of the risks and benefits to the population as a whole (i.e., users and nonusers of tobacco products) in order to protect youth non-users from tobacco product initiation and encourage existing combustible tobacco users to quit or reduce their use [25, 26]. However, it is unknown whether the risk flavored e-cigarettes pose to youth is balanced by their potential to aid in tobacco harm reduction among adult combustible cigarette smokers [27].

The current manuscript reviews and synthesizes the extant empirical literature on e-cigarettes to (a) document the prevalence of flavored e-cigarette use among youth and adults; (b) identify mechanisms through which flavorings enhance product appeal; (c) assess whether flavored e-cigarettes may aid adult combustible cigarette smokers in smoking reduction and cessation; and (d) examine cross-population differences (i.e., smoking status, age, gender, race) in the use and appeal of flavored e-cigarettes.

Methods

Study Selection and Eligibility Criteria

To identify studies for inclusion in the current review, we searched PubMed, Medline, Google Scholar, and PsycINFO beginning in September 2016 and continuing through October 2018 using combinations of the following key words: electronic cigarette, e-cigarette, vapor, vape, vaper, flavor, flavoring, flavour, sweet, fruit, candy, appeal, like, liking, attractiveness, and attractive. No publication date limits were imposed for included articles. This search resulted in a total of 287 journal articles whose abstracts were evaluated for inclusion. Studies were eligible for inclusion if they met the following criteria: (a) the study was peer-reviewed and written in English; (b) the study assessed flavored e-cigarette use (i.e., flavors other than tobacco, including menthol) or appeal among human subjects; (c) the study included original data and was conducted within the USA, or if it was an online survey it contained a portion of US residents; (d) the study differentiated between e-cigarettes and other flavored tobacco products (e.g., combustible cigarettes, cigars); and (e) the study provided the age of participants. Youth were defined as those under the age of 18; young adults were defined within each study using various definitions of young adults, ranging in age from 18 to 34 years of age. Because of the variability in definitions of young adults, and because some studies of adults did not distinguish between young adults and adults, results from young adults are presented with those of all adults. This review was restricted to studies based in the USA in order to define the scope of the review given the wide

variation in regulatory environments in different countries. For the purposes of this review, the term “flavored e-cigarettes” is used to refer to e-cigarette products that contain any non-tobacco flavoring, including menthol, with the exception of flavorless (unflavored) solutions. The term “sweet-flavored e-cigarettes” refers to those labeled by the manufacturer with a confectionary characterizing flavor (e.g., candy, fruit), and excludes menthol, mint, and other non-sweet flavorings (e.g., spice or alcohol) [28, 29].

Data Extraction and Synthesis

The above eligibility criteria resulted in a total of 45 eligible articles (see Fig. 1). To identify additional articles for inclusion, we conducted a manual search of the references in each of the included articles. After searching the references, 9 additional articles were included in this review, resulting in a total of 54 articles. Author NG extracted data and conducted a qualitative synthesis of all included studies.

Results

Prevalence of Flavored E-Cigarette Use Among Youth

Several US cross-sectional surveys have documented the prevalence of flavored e-cigarette use among youth (age \leq 18; Table 1). Data from wave 1 (2013–2014) of the Population Assessment of Tobacco and Health (PATH) study demonstrate that flavored e-cigarettes are frequently used by youth (12–17 years old) at e-cigarette initiation, as 81.0% of e-cigarette ever-users and 85.3% of past 30-day e-cigarette users reported that the first e-cigarette they used was flavored [30], and 80% of youth who vaped before age 15 used flavored e-cigarettes [38••]. In the 2014 National Youth Tobacco Survey (NYTS), 63.3% of adolescent past 30-day vapers (aged 11–18) reported using flavored e-cigarettes (a weighted national estimate of 1.58 million flavored e-cigarette users) [33]. The results of regional studies support and extend these findings; in a 2015 study of Texas youth aged 12 to 17 years old, nearly all of current vapers (97.9%) reported using flavored e-cigarettes and initiating vaping with a flavored e-cigarette (98.6%) [35••].

Preliminary evidence suggests that use of flavored e-cigarettes among youth may be associated with increased frequency and persistence of vaping following initiation. In a cross-sectional study of adolescents taken from 5 different high schools in Connecticut (aged \leq 18), preference for sweet-flavored e-cigarettes was cross-sectionally associated with increased frequency of past 30-day vaping [36••]. Additionally, longitudinal data from this sample suggest that use of e-cigarettes due to the presence of appealing flavorings

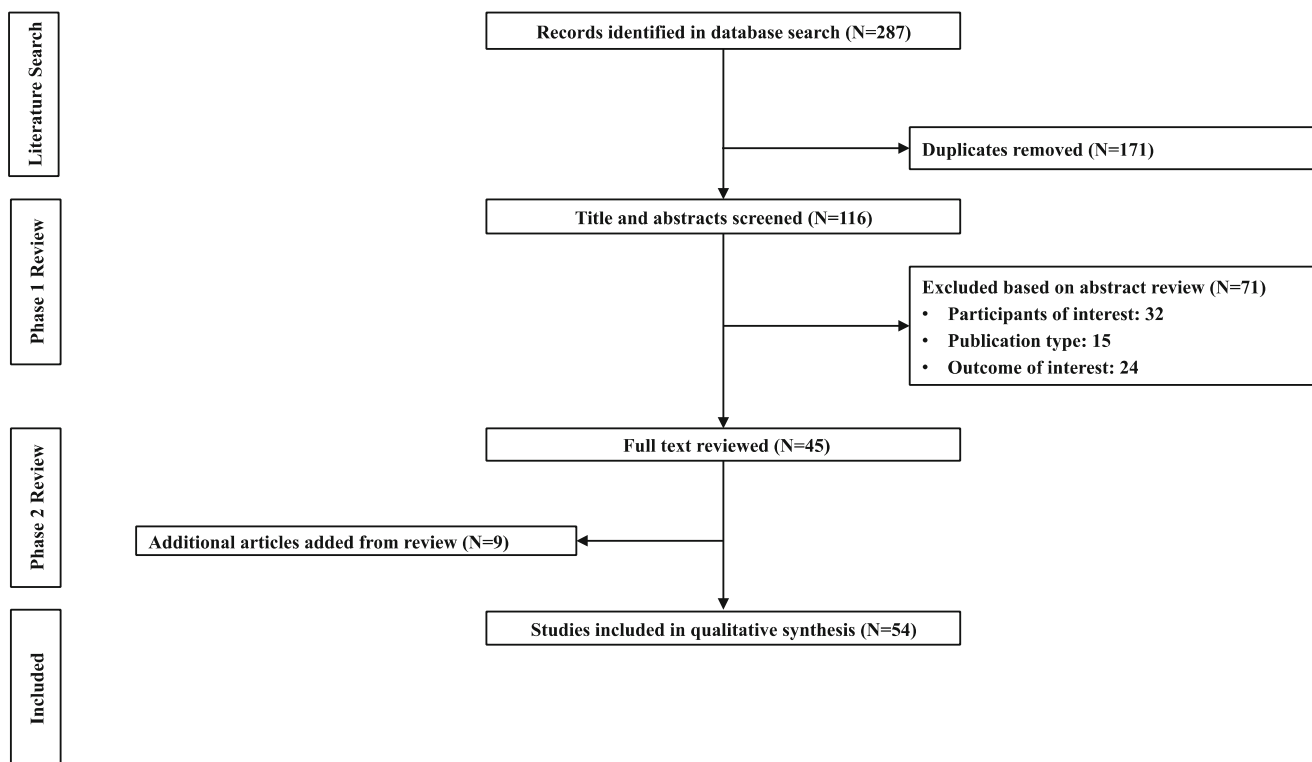


Fig. 1 Flowchart for search and inclusion of reviewed studies. Exclusion for participants of interest, sample did not include US participants. Exclusion for publication type, not original data, not peer-reviewed, not

english language. Exclusion for outcome of interest, study did not assess flavored e-cigarettes

may be associated with continued e-cigarette use at a 6-month follow-up assessment [31••].

Prevalence of Flavored E-Cigarette Use Among Adults

Epidemiological evidence suggests that flavored e-cigarette use has increased among adults (aged ≥ 18 years old) since 2010 [48]. A 2010 qualitative study found that adult vapers ranging in age from 20 to 69 years typically initiated e-cigarette use with tobacco- or menthol-flavored e-cigarettes [46], and in a 2012 national survey of young adult vapers (18–34 years), only 17% reported using flavored e-cigarettes during the past 30 days [51]. A series of online surveys (conducted between 2010 and 2012) found that tobacco-flavored e-cigarettes were most commonly used among adults aged 18 and older [42–44], and that vapers who used tobacco-flavored e-cigarettes were more likely to be recent vapers who started vaping within the past 3 months (vs. long-term users who had vaped for 4 months or longer) [43]. In a 2012 online survey of e-cigarette ever-users, 53.5% of vapers (mean age [M] = 40.1, standard deviation [SD] = 12.7 years) currently used flavored e-cigarettes [52], and in a 2013 telephone survey, 51% of participants (aged 18+) reported current use of flavored e-cigarettes and 45% of e-cigarette ever-users reported using a flavored e-cigarette when they initiated vaping [49].

More recent data suggests that the prevalence of flavored e-cigarette is increasing among adults and may have surpassed that of tobacco- and menthol-flavored e-cigarettes. Data from the 2014–2015 PATH study demonstrate that 64.6% of adult past 30-day vapers (aged ≥ 25) and 69% of young adults (aged 18–24) used flavored e-cigarettes [37, 38••], and in the 2014 National Adult Tobacco Survey (NATS), 68.2% of past 30-day vapers (aged 18+) used flavored e-cigarettes (a weighted estimate of 10.2 million adults) [40]. In two online surveys conducted between 2013 and 2014, over 67% of adults (aged 18+) used sweet-flavored e-cigarettes [39, 45], and in a 2015 national study, 74% of young adults (ages 18–29) and 47% of older adults (age ≥ 30) reported using flavored e-cigarettes [35••]. Regional studies support this trend: in two 2013 surveys, 68.2% and 81.4% of Florida and Midwestern adult vapers (aged 18+), respectively, used flavored e-cigarettes [47, 50]. By 2015, 96.7% of Texas young adult e-cigarette users (18–29 years old) reported currently using flavored e-cigarettes and 95.2% initiated e-cigarette use with flavored e-cigarettes (33).

Appeal of Flavored E-Cigarettes Among Youth

Data from surveys and focus groups with adolescents (12–18 years old) indicate that flavored e-cigarettes are appealing due to their pleasant taste and attractive sensory characteristics

Table 1 Prevalence of flavored E-cigarette use among youth and adults

Citation	Population	Study design	Major findings
Prevalence of flavored E-cigarette use among youth Ambrose et al. (2015) [30]	13,651 youth <i>M</i> age (<i>SD</i>) = 14.5 (0.02)	Cross-Sectional Survey National Study (PATH)	81.0% of ever-vapers reported using a flavored e-cigarette at initiation 85.3% of past 30-day vapers reported currently using flavored e-cigarettes
Bold et al. (2016) [31••]	340 youth ever-vapers <i>M</i> age (<i>SD</i>) = 15.6 (1.2)	Longitudinal Survey Connecticut	Initial use e-cigarettes due to the presence of “good” flavorings predicted continued e-cigarette use and more frequent past 30-day e-cigarette use at 6-month follow-up
Chen et al. (2017) [32•]	18,392 youth Age 11–18	Cross-Sectional Survey National Study (NYTS)	Flavored e-cigarette use was associated with increased susceptibility to combustible cigarette smoking among non-smoking youth (aOR = 3.8; <i>p</i> < 0.0001)
Corey et al. (2014) [33]	22,007 youth Age 11–18	Cross-Sectional Survey National Study (NYTS)	63.3% of current vapers used flavored e-cigarettes An estimated 1.58 million high school and middle school students used a flavored e-cigarette in 2014
Dai et al. (2016) [34••]	2017 adolescents Past 30-day vapers Age 11–18	Cross-Sectional Survey National Study (NYTS)	60.9% of past 30-day vapers reported using flavored e-cigarettes Flavored e-cigarette use was associated with increased intentions to initiate combustible cigarette use among never-smokers (aOR = 5.7; <i>p</i> < 0.0001) Flavored e-cigarette use was associated with reduced intentions to quit tobacco use among smokers (aOR = 0.6; <i>p</i> = .006)
Harrell et al. (2016) [35••]	3907 Youth Age 12–17	Cross-Sectional Survey Texas	97.9% of ever-vapers reported using flavored e-cigarettes 98.6% of vapers initiated e-cigarette use with a flavored e-cigarette
Morean et al. (2018) [36••]	396 high school vapers <i>M</i> age (<i>SD</i>) = 16.18 (1.2) 42.2% smokers	Cross-Sectional Survey Connecticut	Preferences for fruit- and dessert-flavored e-cigarettes were significantly associated with increased frequency of past 30-day e-cigarette use (<i>ps</i> < 0.007).
Schneller et al. (2018) [37]	415 youth vapers Age 12–17	Cross-Sectional Survey National Study (PATH)	79.3% of youth reported using flavored e-cigarettes
Villanti et al. (2017) [38••]	13,651 youth Age 12–17	Cross-Sectional Survey National Study (PATH)	81% of youth reporting using a flavored e-cigarette at first use 80% of youth who vaped before age 15 used a flavored e-cigarette
Prevalence of flavored E-cigarette use among adults Berg (2016) [39]	Vapers and Smokers Age 18–34 59.3% smokers	Cross-Sectional Survey Online	67% of current vapers used sweet-flavored e-cigarettes 60.2% used e-cigarettes because, “They come in appealing flavors” 59.5% used e-cigarettes because, “I like experimenting with various flavors”
Bonhomme et al. (2016) [40]	3434 adult vapers Age 18–65+	Cross-Sectional Survey	68.2% of adult vapers used flavored e-cigarettes
Chen et al. (2018) [41]	12,383 young adults Age 18–34	Prospective Survey National Study (PATH) Online Survey	69.9% of young adult vapers used flavored e-cigarettes
Dawkins et al. (2013) [42]	1347 vapers Age <i>M</i> (<i>SD</i>) = 43.4 (12.0) 16% smokers	Online Survey	Tobacco (53%) was the most commonly used flavoring, followed by fruit (33%), menthol (28%) and chocolate/sweet (18%)
Etter (2016) [43]	2807 vapers Age <i>Median</i> (<i>IQR</i>) = 41 (31–50) 80% former smokers 20.6% US residents	Online Survey	Tobacco was the most commonly used flavor (35%) followed by fruit (18%), menthol (14%) Tobacco-flavored e-cigarettes were used by 44% of recent vapers (vaped 0–3 months) and 25% of long-term vapers (vaped ≥ 4-months)
Etter et al. (2011) [44]	3587 vapers 70% former smokers Age <i>Median</i> (<i>IQR</i>) = 41 (31–50)	Online Survey	39% used tobacco-flavored e-cigarettes 15% used menthol-flavored e-cigarettes 14% used fruit-flavored e-cigarettes

Table 1 (continued)

Citation	Population	Study design	Major findings
Farsalimos et al. (2013) [45]	4618 adult vapers Age Median (IQR) = 40 (32–49) 91.2% former smokers 48.5% US residents	Online Survey	Fruit- (69.4) and sweet-flavored (61.4%) e-cigarettes were the most commonly used by current vapers Tobacco (69.1%) was the most common flavor used at e-cigarette initiation
Harrell et al. (2016) [33••]	5482 young adults age 18–29, 6,051 adults (age ≥ 30)	Cross-Sectional Survey	96.7% of young adults used flavored e-cigarettes 95.2% initiated e-cigarette use with a flavored e-cigarette Fruit flavors were the most popular (83%) followed by candy/dessert (52%) and tobacco (23%) 74.0% of adult vapers reported using a flavored e-cigarette
McQueen et al. (2011) [46]	210 adult vapers Age: 18+	Qualitative Interviews Midwest	New vapers generally initiated e-cigarette use with tobacco or menthol flavored nicotine solutions
Nonnemaker et al. (2016) [47]	365 adult vapers Age 19–65+	Cross-Sectional Survey Florida	60.4% of current e-cigarette users used menthol-flavored e-cigarettes 56.6% used candy-flavored e-cigarettes 31.8% used tobacco-flavored e-cigarettes
Russell et al. (2018) [48]	20,676 adult frequent e-cigarette users Age $M (SD) = 42.5 (11.6)$ 15.2% ≤ 25 years of age	Online Survey USA	In 2011, 44.8% of first e-cigarette purchases were tobacco-flavored In 2011, 17.9% of first e-cigarette purchases were fruit-flavored In 2016 20.8% of first e-cigarette purchases were tobacco-flavored In 2016 36.6% of first e-cigarette purchases were fruit-flavored
Schneller et al. (2018) [37]	2123 adult past 30-day vapers Age 18+	Cross-Sectional Survey National Study (PATH)	64.6% of adults reported using a flavored e-cigarette
Smith et al. (2016) [49]	1443 adult tobacco users Age 18+	Telephone Survey	51% of participants reported current use of flavored e-cigarettes
Tackett et al. (2015) [50]	215 adult vapers M age (SD) = 36.23 (12.97)	Cross-Sectional Survey Midwestern States	45% initiated vaping with flavored e-cigarettes 46.7% vaped fruit-flavored e-cigarettes 23.7% vaped candy- or dessert-flavored e-cigarettes 18.6% vaped tobacco-flavored 9.0% vaped menthol-flavored e-cigarettes
Villanti et al. (2017) [38••]	3887 young adult vapers (ages 12–17) 7635 adult vapers (ages 18+)	Cross-Sectional Survey National Sample (PATH)	61% of young adult vapers used flavored e-cigarettes 46% of adult vapers used flavored e-cigarettes
Villanti et al. (2013) [51]	4196 young adults Age 18–34	Cross-Sectional Survey National sample	70 participants (1.7%) used e-cigarettes during the past 30-days 17% of past 30-day vapers used flavored e-cigarettes
Yingst et al. (2015) [52]	4421 ever-vapers M age (SD) = 40.1 (12.7)	Online survey	53.5% used flavored e-cigarettes

Citations are presented in alphabetical order. MTF, Monitoring the Future; NYTS, National Youth Tobacco Survey; PATH, Population Assessment of Tobacco and Health Study; NATS, National Adult Tobacco Survey; OR, odds ratio. aOR, adjusted odds ratio; Vaper, E-cigarette user. Youth < 18 years of age. Adults ≥ 18 years of age

Table 2 Appeal/risk perceptions of flavored E-cigarettes among youth and adults

Citation	Population	Study design	Major findings
Appeal and risk perceptions of flavored E-cigarettes among youth Ambrose et al. (2015) [30]	13,651 youth <i>M</i> age (<i>SD</i>) = 14.5 (0.02)	Cross-Sectional Survey National Study (PATH)	81.5% of vapers cited appealing flavors as a reason for e-cigarette use
Cooper et al. (2016) [53]	3907 Youth 5482 young adults 32.1% 6th graders 34.5% 8th graders 33.4% 10th graders	Cross-Sectional Survey Texas	Youth who currently used e-cigarettes had higher odds of describing flavored (vs. non-flavored) e-cigarettes as “less harmful” (aOR = 2.84, 95% CI: 1.91, 4.21)
Harrell et al. (2017) [54••]	2483 youth Age 12–17	Cross-Sectional Survey Texas	78% of youth said they would no longer use e-cigarettes if flavorings were not available
Harrell et al. (2016) [35••]	3907 youth Age 12–17	Cross-Sectional Survey	72.9% of vapers used e-cigarettes because they, “Come in flavors I like”
Kong et al. (2015) [14]	5405 middle, high school and college students MS <i>M</i> age (<i>SD</i>) = 12.2 (0.9) HS <i>M</i> age (<i>SD</i>) = 15.6 (1.2) College <i>M</i> age (<i>SD</i>) = 22.1 (5.5)	Cross-Sectional Survey Focus Groups	Fruit flavors were the most popular (76%), followed by candy/dessert, (57%) and tobacco (13%) 43.8% of ever-vapers cited the availability of appealing flavorings as a key reason for experimentation with e-cigarettes
Krishnan-Sarin et al. (2017) [55•]	60 adolescent and young adult vapers <i>M</i> age (<i>SD</i>) = 18.8 (.8)	Laboratory Study	Significant main effect of menthol on appeal ($p = 0.006$), with 3.5% menthol ($M = 43.4$) rated higher than 0% menthol ($M = 34.3$). Significant main effect of menthol on improved taste ($p = 0.006$), with 3.5% menthol ($M = 18.52$) and 0.5% menthol ($M = 21.40$) rated higher than 0% menthol ($M = 5.07$) Significant main effect of menthol on sensory coolness ($p < 0.0001$), perceived coolness increased at each successive increase in menthol concentration
Patrick et al. (2016) [56]	4066 high school students (8th, 10th, 12th grades)	Cross-Sectional Survey National Study (MTF)	Good taste was the second most common reason for e-cigarette use among ever-vapers (37.2%) Good taste was the most common reason for vaping among frequent users
Pepper et al. (2016) [57]	1125 adolescents <i>M</i> age (<i>SD</i>) = 15.1 (1.4) 4% smokers 5% vapers	Experimental Survey	Adolescents stated they were more likely to try menthol-flavored (OR = 4.00; $p < 0.01$) candy-flavored (OR = 4.53; $p < 0.01$) or fruit-flavored e-cigarettes (OR = 6.49, $p < 0.001$) than tobacco-flavored e-cigarettes Adolescents perceived fruit-flavored e-cigarettes to be less harmful than tobacco-flavored e-cigarettes ($p < 0.05$)
Tsai et al. (2018) [58]	1061 middle school ever-vapers 2988 high school ever-vapers	Cross-Sectional Survey National Study (NYTS)	Harm perceptions were partially explained (mediated) the relationship between flavor type and interest in trying e-cigarettes ($p < 0.01$) 31.0% of participants cited the availability of, “flavors such as mint, candy, fruit, or chocolate” as a reason for vaping 41.1% of past 30-day e-cigarette-only users and 46.0%, of dual users used e-cigarettes because, “they are available in flavors, such as mint, candy, fruit, or chocolate” “Comes in flavors that I like” was the most highly ranked reason for e-cigarette use among vapers
Villanti et al. (2017) [38••]	13,651 youth Age 12–17	Cross-Sectional Survey National Study (PATH)	The wide variety of available sweet e-cigarette flavors are appealing
Wagoner et al. (2016) [59]	21 adolescents Age 13–17	Focus Group	Pleasant orosensory (gustatory) sensations are a primary reason for flavored e-cigarette use
Appeal of flavored E-cigarettes among adults Amato et al. (2016) [60]	9301 Adults Age 18+ 32 smokers Age <i>M</i> (<i>SD</i>) = 25.0 (3.0) 56% menthol smokers	Cross-Sectional Survey Minnesota Laboratory study	Current vapers (vs. former vapers) cited the availability of sweet- and menthol-flavored e-cigarettes as reasons for use Sweet-flavored e-cigarettes were rated as more rewarding ($p = 0.001$) Participants were willing to work harder to earn puffs from a sweet-flavored e-cigarette than flavorless ($p < 0.0001$) and took more puffs from the sweet-flavored e-cigarettes during ad-lib vaping (IRR = 2.03; $p = 0.01$)
Audrain-McGovern et al. (2016) [61]	36 smokers Age <i>M</i> (<i>SD</i>) = 36.1 (15.3)	Longitudinal study	Flavors differentiate e-cigarettes from other nicotine replacement products The availability of appealing flavors was a commonly cited reason for e-cigarette use
Berg et al. (2014) [62]	12,383 young adults Age 18–34 30 young adult vapers Age <i>M</i> (<i>SD</i>) = 25 (3.8) 77% current smokers	Prospective Survey National Study (PATH) In-Person Interviews	Participants who perceived e-cigarettes as less harmful than cigarettes were more likely to use flavored e-cigarettes (aOR [95% CI] = 1.59 [1.15–2.19] $p = 0.005$) Vapers cite flavored e-cigarettes were a primary attraction and reason for vaping
Eiter et al. (2011) [44]	3587 vapers Age <i>Median</i> (IQR) = 41 (31–50) 70% former smokers	Online Survey	Tobacco-flavored e-cigarettes were rated as less satisfying than sweet and menthol flavorings ($p < 0.01$)

Table 2 (continued)

Citation	Population	Study design	Major findings
Farsalinos et al. (2013) [45]	4618 adult vapers Age <i>Median</i> (<i>IQR</i>) = 40 (32–49) 91.2% former smokers	Online Survey	Fruit (69.4%) and sweet (61.4%) flavors were the most commonly used at the time of the survey Tobacco (69.1%) was the most commonly used flavor at initiation
Farsalinos et al. (2015) [64]	7060 vapers Age <i>Median</i> (<i>IQR</i>) = 38 (30–46)	Online Survey	38.6% of vapers listed the variety of flavorings in e-cigarettes as a reason for initiating vaping
Goldenson et al. (2016) [65]	20 young adult vapers Age <i>M</i> (<i>SD</i>) = 26.3 (4.6)	Laboratory Study	Sweet-flavored solutions produced greater subjective appeal and perceptual sweetness than non-sweet (tobacco and menthol) e-cigarettes ($p < 0.0001$).
Harrell et al. (2017) [35••]	4326 young adults Age 18–29	Cross-Sectional Survey Texas	Sensory sweetness was positively associated with appeal across all flavorings ($ps < 0.0001$) 73.5% of young adults said they would no longer use e-cigarettes if flavorings were not available
St Helen et al. (2018) [66•]	14 adult vapers Age <i>M</i> (<i>SD</i>) = 32.3 (13.8)	Laboratory Study	Average puff duration was significantly longer when using a strawberry e-liquid (M [<i>SD</i>] = 3.2 [1.3] s) compared to the tobacco e-liquid M [<i>SD</i>] = (2.8 [1.1] s)
Kim et al. (2016) [67]	35 adult vapers Age 18–65 65% smokers	Focus group	Flavor is an exciting and fun e-cigarette product feature Favorite flavors included fruits, sweet/dessert and menthol/mint E-cigarette-only Fruit and sweet/dessert flavors reduce the harshness of nicotine The enjoyment of flavored e-cigarettes was associated with use of recent-generation e-cigarette devices (e.g., advanced personal vaporizers, mods)
Kim et al. (2016) [67]	31 e-cigarette users Age <i>M</i> (<i>SD</i>) = 33.6 (10.9) 61% smokers	Laboratory Study	Sweet-flavored solutions produced greater subjective appeal ($p < 0.05$) Appeal was positively correlated with sensory sweetness and coolness ($ps < 0.0001$) Appeal was inversely correlated with bitterness ($p < 0.01$) Menthol was significantly cooler than the sweet and tobacco flavorings ($p < 0.01$) Menthol (32%) was rated as the most appealing flavor followed by cherry (30%) tobacco (24%), chocolate (10%) and flavorless (4%) Flavored e-cigarettes are attractive to vapers and non-vapers Flavored e-cigarettes encourage e-cigarette initiation
Litt et al. (2016) [68]	88 smokers Age 18–55	Laboratory Study	
McDonald et al. (2015) [69]	87 young adults Age 18–27 32% vapers	Field Study (cessation trial) Focus Groups Semi-Structured Interviews	
Nonnemaker et al. (2016) [47]	66% smokers 365 adult vapers Age 19+	Cross-Sectional Survey Florida	Among vapers and cigarette smokers, the absence of flavors significantly reduced the price participants were willing to pay for e-cigarettes
Pokhrel et al. (2015) [70]	62 young adults <i>M</i> age (<i>SD</i>) = 25.1 (5.5)	Focus Group	Flavorings and sensory satisfaction (i.e., pleasant smell and taste) contribute to the appeal of e-cigarettes
Rosbrook et al. (2016) [71]	32 adult smokers Age 18–45	Laboratory study	Menthol increased appeal independently of nicotine ($p < 0.0001$) Menthol increased perceived coolness ($p < 0.0001$) Menthol reduced airway irritation/harshness produced by nicotine ($p < 0.0001$)
Soule et al. (2016) [72]	81% menthol-smokers 16%–38% vapers 46 adult vapers Age <i>M</i> (<i>SD</i>) = 35.1 (10.6)	Concept Mapping Mixed-Method	“Increased satisfaction and enjoyment” and “better feel and taste than [combustible] cigarettes” were the two most commonly cited reasons for flavored e-cigarette use Flavored e-cigarette solutions increase sensory satisfaction, mask the aversive taste of nicotine and increase the reward of e-cigarettes The variety of available flavors are appealing Good smell is a reason for flavored e-cigarette use 85.4% described variety of flavor choices as important
Wagoner et al. (2016) [59]	56 young adults Age 18–25	Focus Group	
Yingst et al. (2015) [52]	4421 vapers <i>M</i> age (<i>SD</i>) = 40.1 (12.7)	Online survey	

Citations are presented in alphabetical order

MTF, Monitoring the Future; PATH, Population Assessment of Tobacco and Health Study; NATS, National Adult Tobacco Survey; OR, odds ratio; aOR, adjusted odds ratio; Vaper, E-cigarette user. Youth < 18 years of age. Adults ≥ 18 years of age

Dual user, concurrent e-cigarette and combustible cigarette user

(Table 2) [30, 38•, 56, 59]. In a national survey of adolescent e-cigarette users (12–17 years old), 81.5% stated they used e-cigarettes, “because they come in flavors I like” [30], and among a national sample of high school students, the second most common reason for e-cigarette use (after experimentation) was because of their good taste [56]. In a 2016 survey of US middle and high school e-cigarette ever-users, the second most commonly selected reason for using e-cigarettes (after use by friends or family members) was “they are available in flavors, such as mint, candy, fruit, or chocolate” [58]. In a survey of Texas youth aged 12–17 years, 72.9% reported using e-cigarettes because of the availability of appealing flavorings [35•], with fruit (76%) and candy (57%) being the most commonly used flavorings [35•]. Importantly, 78% of flavored youth e-cigarette users in this sample stated that they would no longer vape if flavored e-cigarettes were not available [54•].

A controlled laboratory study of adolescent and young adult vapers (16–20 years of age) assessed the appeal and rewarding effects of menthol and nicotine in e-cigarettes [55•]. Sixty current vapers (M age = 18.8; SD = 0.8) self-administered e-cigarettes at three different menthol concentrations (0%, 0.5%, or 3.5% menthol) at a single randomly assigned nicotine condition (0, 6, or 12 mg/ml) and then rated the appeal and sensory effects of each condition. There was a significant main effect of menthol, with the highest menthol concentration (3.5%) significantly increasing e-cigarette appeal, compared to 0% menthol. Both menthol concentrations (0.5% and 3.5%) significantly improved taste and enhanced perceived coolness [55•].

Perceived Harm of Flavored E-Cigarettes Among Youth

Research also suggests that adolescents perceive flavored e-cigarettes as less harmful than unflavored e-cigarettes (Table 2). In a school-based survey conducted among 6th, 8th, and 10th graders, current vapers were more likely to describe flavored e-cigarettes as less harmful than tobacco-flavored e-cigarettes [53]. A telephone survey that randomly assigned adolescents (M age = 15.1, SD = 1.4) to one of five flavor conditions (i.e., tobacco, alcohol, menthol, candy, fruit) found that participants perceived sweet- and menthol-flavored e-cigarettes as significantly less harmful than tobacco-flavored e-cigarettes, and were significantly more likely to express interest in trying candy- (OR [95% CI] = 4.53 [1.67, 12.31]), fruit- (OR [95% CI] = 6.49 [2.48, 17.01]), and menthol-flavored e-cigarettes (OR [95% CI] = 4.00, [1.46, 10.97]), compared to tobacco-flavored cigarettes [57]. Subsequent mediation analyses revealed that perceived harmfulness explained a significant portion of the association between flavorings and interest in trying e-cigarettes [57].

Appeal of Flavored E-Cigarettes Among Adults

Qualitative evidence demonstrates that the pleasurable taste, pleasant smell, and ability of flavorings to reduce the harshness of nicotine contribute to the appeal of flavored e-cigarettes among adults over the age of 18 (Table 2; [59, 60, 62, 63, 69, 70, 73]). In focus groups and interviews, adult and young adult vapers note that flavored e-cigarettes encourage initiation of vaping [64, 69], and a concept mapping approach (grouping answers to prompts into clusters representing common themes) identified (a) “increased satisfaction and enjoyment;” and (b) “better feel and taste than [combustible] cigarettes” as the two most common reasons for flavored e-cigarette use [72]. In surveys, adult vapers ($median$ age = 41.0, interquartile range [IQR] = 32–49 years) rated sweet- and menthol-flavored e-cigarettes as more satisfying than tobacco-flavored e-cigarettes [44], and 85.4% of vapers (M age = 40.1, SD = 12.7) described the variety of flavor choices as an important reason for vaping [52]. Additionally, adult smokers aged 19 years and above stated they would pay more money for flavored (vs. unflavored) e-cigarettes [47].

Research suggests that flavored e-cigarettes may be particularly important for young adults. In a survey of young adults residing in Texas (aged 18–29), 73.5% of flavored e-cigarette users stated they would no longer use e-cigarettes if flavored products were not available [54•]. Additionally, in a national prospective survey of young adults (18–34 years old), perceptions of e-cigarettes as less harmful than combustible cigarettes were prospectively associated with flavored e-cigarette use, compared to tobacco- and menthol-flavored e-cigarettes [41].

Controlled laboratory evidence demonstrates that e-cigarettes are appealing and reinforcing among adults. In two e-cigarette administration experiments that utilized similar methodologies, current vapers (M age = 26.3 and 33.6 years; 61% and 80% smokers, respectively) rated the subjective appeal and sensory effects (i.e., sweetness and bitterness) of flavored and unflavored e-cigarettes [65, 67]. Fruit- and candy-flavored e-cigarettes (vs. tobacco-, menthol-, and flavorless e-cigarettes) were significantly more appealing and were rated as being subjectively sweeter [65, 67]. Across all flavorings, appeal was positively associated with perceived sweetness and inversely correlated with bitterness [65, 67].

In a laboratory study designed to identify flavor preferences for a subsequent smoking reduction trial, 88 non-treatment-seeking adult smokers (M age = 25.0, SD = 3.0) administered tobacco, menthol, chocolate, and cherry-flavored e-cigarettes; menthol and cherry were rated as more appealing than the tobacco flavor [61]. Another laboratory study of e-cigarette-naïve smokers (aged 18–55) found that sweet-flavored e-cigarettes (i.e., fruit and chocolate) were rated as significantly more rewarding than an unflavored (i.e., flavorless) e-cigarette [68•]. These subjective ratings were

supported by two behavioral tasks: (a) in a progressive ratio task (i.e., task designed to assess willingness to work for a reward), participants worked nearly six-times harder for the sweet-flavored (vs. flavorless) e-cigarettes; and (b) in a 90-min ad-lib vaping period, participants self-administered the sweet-flavored e-cigarette nearly twice as frequently than the flavorless control [61]. An additional experimental study suggests that sweet flavorings may affect vaping topography, as vapers (M age = 32.3, SD = 13.8) took longer puffs when using sweet-flavored (vs. tobacco-flavored) e-cigarettes [66•].

Laboratory studies have also focused specifically on the sensory effects of menthol-flavored e-cigarettes. Vapers aged 18 and above (61% smokers) rated menthol as significantly “cooler” than e-cigarettes with sweet and tobacco flavorings, and coolness was positively associated with appeal [67]. In a study of adult smokers (18–45 years old; 16–38% vapers) that manipulated menthol and nicotine concentrations, e-cigarettes with higher menthol concentrations enhanced perceptions of coolness and decreased the harshness of nicotine [71], and menthol significantly enhanced the intensity of the overall sensory experience, particularly at lower nicotine concentrations [71].

Use of Flavored E-Cigarettes for Smoking Reduction and Cessation Among Adult Smokers

Data from observational and qualitative studies suggest that flavored e-cigarettes may aid adult smokers in smoking reduction and cessation efforts (Table 3). Former smokers cite the wide variety of available flavorings and superior taste of e-cigarettes as factors that aid smoking cessation [43, 45, 63], and note that restricting the availability of flavorings would make the vaping less enjoyable and reduce the appeal of e-cigarettes [45, 74]. In a study of adult vape store customers (M age = 36.23, SD = 12.97), flavored e-cigarette users (vs. unflavored users) were more likely to have quit smoking [50], and in an online cross-sectional survey, adult e-cigarette users (M age = 42.5, SD = 11.6), who had switched from smoking cigarettes to vaping were more likely to have initiated e-cigarette use with non-tobacco flavors [48]. A longitudinal cohort study of adult smokers (age \geq 18 years) found that use of flavored e-cigarettes was associated with lower self-reported daily intensity (i.e., cigarettes/day) of cigarette smoking [75], and in a national sample of 18 to 34-year-old young adult smokers, use of flavored (vs. tobacco-flavored) e-cigarettes was prospectively associated with self-reported smoking reduction or cessation [76••].

In the sole smoking reduction trial that utilized flavored e-cigarettes, smokers aged 18–55 were randomly assigned to one of four experimental conditions for a 6-week period according to a flavor (i.e., tobacco vs. menthol vs. sweet [cherry or chocolate]) \times nicotine (i.e., 0 mg/ml vs. 18 mg/mL) design and smoking and vaping behavior was assessed with a timeline follow-back method, daily interactive voice response

recordings, and weekly breath carbon monoxide readings [68••]. Participants assigned to the menthol conditions experienced the greatest reduction in daily smoking, followed by cherry and tobacco, while those assigned to chocolate condition experienced the smallest reduction in smoking [68••]. However, participants in the tobacco-flavored e-cigarette condition vaped most frequently (12.3 vaping episodes per day), and participants assigned to the chocolate-flavored e-cigarette displayed the lowest intensity of daily vaping (8.6 episodes per day).

Factors That Moderate the Use and Appeal of Flavored E-Cigarettes

Differences in Flavored E-Cigarette Use by Combustible Cigarette Smoking Status

Evidence suggests that use of flavored e-cigarettes may be associated with combustible cigarette smoking among youth (Table 4). In a cross-sectional survey, use of flavored e-cigarettes by never-smokers was associated with increased susceptibility to combustible cigarette smoking [32•, 34••], and smokers who used flavored e-cigarettes were less likely to report intentions to quit smoking, compared to youth smokers who used unflavored e-cigarettes and non-users [34••]. Smokers may also be more likely to use e-cigarettes with traditional flavorings, as suggested in a recent study that found a greater proportion of Connecticut high school students who were current smokers reported preferring tobacco—(7.1%) and menthol-flavored (18.6%) e-cigarettes as compared to never-smokers (0.5% tobacco, and 3.5% menthol). However, a greater proportion of current smokers also preferred sweet flavors (62.0%) vs. never-smokers (52.1%) suggesting more positive endorsement of any flavors (traditional or nontraditional) among the group of current cigarette smokers [77].

Data also indicate that adult smokers (aged 18+) may use tobacco-flavored e-cigarettes at higher rates than nonsmokers (Table 4) [39, 40, 42, 45, 73]. In online surveys, few adult never-smokers (6.1%) used tobacco-flavored e-cigarettes, and current smokers used tobacco-flavored e-cigarettes at higher rates than former smokers [39, 44, 45]. Additionally, concurrent users of e-cigarettes and combustible cigarettes (dual users) initiated vaping with tobacco-flavored e-cigarettes at higher rates than exclusive e-cigarette users [35••]. Smokers and dual users (vs. nonsmokers) also report that they would pay less money for flavored e-cigarettes [47], and heavier smokers (vs. lighter smokers) expressed a preference for tobacco-flavored (vs. flavored) e-cigarettes [78].

Differences in Flavored E-Cigarette Use by Age

Studies demonstrate that younger age is associated with higher rates of flavored e-cigarette use [38••, 40, 78]. A

Table 3 Use of flavored E-cigarettes for smoking reduction and cessation among adult smokers

Citation	Population	Study design	Major findings
Barbeau et al. (2013) [74]	11 vapers Age 18–64	Focus group	Flavorings were related to smoking reduction and cessation
Buu et al. (2018) [75]	2727 smokers Age 18+	Prospective Survey National Study (PATH)	Use of flavored e-cigarettes was associated with lower daily quantity of cigarette smoking at 1-year follow-up ($B = -2.89$; $p < 0.05$)
Chen et al. (2018) [76••]	4645 young adult smokers (age 18–34)	Prospective Survey National Study (PATH)	Use of flavored e-cigarettes (aOR [95% CI] = 2.5 [1.6, 3.8]; $p < 0.001$) and use of multiple flavorings (aOR [95% CI] = 3.0 [2.1, 4.3]; $p < 0.001$) were associated with smoking reduction or cessation, compared to no e-cigarette use.
Cheney et al. (2016) [63]	30 young adult vapers Age M (SD) = 25 (3.8) 77% current smokers	In-Person Interviews	Former smokers cited flavorings as a primary reason for e-cigarette use
Etter (2016) [43]	2807 vapers Age $Median$ (IQR) = 41 (31–50) 80% former smokers	Online Survey	80% of participants stated that flavors helped them quit or reduce cigarette smoking Former smokers expressed a preference for fruit or menthol flavors and cited flavored e-cigarettes as helpful in reducing and quitting smoking
Farsalinos et al. (2013) [45]	4618 adult vapers Age $Median$ (IQR) = 40 (32–49) 91.2% former smokers 48.5% US residents	Online Survey	68.9% reduced availability of flavored e-cigarettes would make vaping less enjoyable Flavored e-cigarettes “very important” for reducing or quitting smoking 39.7% the reduced availability of flavored e-cigarettes would make reducing or quitting smoking less likely Former smokers noted that restricting the availability of flavorings could make smoking cessation and reduction more difficult
Litt et al. (2016) [68••]	88 smokers Age 18–55	Laboratory Study Smoking reduction trial	Menthol-flavored e-cigarettes resulted in the greatest decrease in cigarette consumption ($p < 0.05$) Participants vaped tobacco-flavored e-cigarettes most frequently ($p < 0.001$)
Russell et al. (2018) [24]	20,676 adult frequent e-cigarette users Age M (SD) = 42.5 (11.6) 15.2% ≤ 25 years of age	Cross-sectional online survey	Switchers, dual users, and former smoker (vs. never-smokers) were significantly less likely to initiate e-cigarette use with sweet-flavored e-cigarettes (ORs = 0.41–0.58; $ps < 0.001$) and to currently use sweet flavors (ORs = 0.64–0.70; $ps < 0.001$)
Tackett et al. (2015) [50]	215 vapers M age (SD) = 36.23 (12.97)	Cross-Sectional Survey Midwest	Vapers who used sweet-flavored e-cigarettes were more likely to have quit smoking (OR [95% CI] = 2.4 [1.07, 5.53]; $p = 0.035$)

Citations are presented in alphabetical order. OR, Odds ratio; aOR, adjusted odds ratio; Vaper, E-cigarette user. Adults ≥ 18 years of age

larger proportion of young adults (compared to older adults) report current flavored e-cigarette use [35••, 38••, 40], and younger age has been shown to be associated with increased odds of using flavored e-cigarettes at vaping initiation [35••, 49]. In wave 1 of the PATH study (2013–2014), flavored e-cigarette use was highest among youth (85.3%), followed by young adults (83.4%) and was lowest in adults over 25 years of age (63.2%) [38••]. Furthermore, among young adults (aged 18–34), younger age was associated with flavored e-cigarette use [57], and youth (12–17 years old) were significantly more likely than adults to report using fruit-flavored e-cigarettes and less likely to report using menthol- or mint-flavored e-cigarettes [37]. Similarly, more Texas youth (72.9%) than young adults (57.4%) cited flavorings as a reason for e-cigarette use [35••], and in a sample of Connecticut youth, 47.0% of high school students, compared to 32.8% of college students, cited flavorings as a reason for experimentation with e-cigarettes [13]. In qualitative studies, young adult vapers (aged 18–45) emphasize the importance of sweet flavorings and their ability to reduce the harshness of nicotine [40, 72, 73], while older adult

vapers (aged 45–65) express a preference for the taste of tobacco-flavored e-cigarettes [73].

Gender and Race Differences in Flavored E-Cigarette Use

Data suggest that the use, appeal, and sensory effects of flavored e-cigarettes, particularly menthol, may also vary by gender. Qualitative interviews and observational surveys of adults (18+) suggest that more females (vs. male) vapers use flavored e-cigarettes [41, 42, 80, 82]. An experiment with menthol-flavored e-cigarettes found a three-way interaction between menthol, nicotine content, and female gender, with females (18–45 years of age) preferring menthol-flavored e-cigarettes, particularly in the absence of nicotine [71]. In a separate study of non-treatment seeking smokers (M age = 42.2, $SD = 9.7$), female menthol smokers (vs. males) vaped less and rated e-cigarettes as less rewarding when presented with a tobacco-flavored e-cigarette [81].

Several studies have examined race differences in flavored e-cigarette use. In a cross-sectional survey of students in 8th, 10th, and 12th grade, significantly more White (38.9%) than

Table 4 Factors that moderate the use of flavored E-cigarettes among youth and adults

Citation	Population	Study design	Major findings
Differences in flavored E-Cigarettes use by smoking status Berg (2016) [39]	Vapers and Smokers Age 18–34 832 current vapers 468 former vapers 267 never-vapers 3434 adult vapers Age 18+ 18,392 youth Age 11–18 2017 adolescents Past 30-day vapers Age 11–18	Online survey	Current smokers used menthol-flavored e-cigarettes the most frequently (36.4%), followed by never-smokers (34.7%) and past smokers (22.8%) More current cigarette smokers (27.4%) than never-smokers (6.1%) or former smokers (15.4%) used tobacco flavors
Bonhomme et al. (2016) [40]	3434 adult vapers Age 18+	Cross-sectional Survey National Adult Tobacco Survey (NATS)	Never-smokers (84.8%) had the highest proportion of flavored e-cigarette use, followed by recent former smokers (7.8.1%), long-term former smokers (70.4%) and current cigarette smokers (63.2%). Flavored e-cigarette use was associated with increased susceptibility to combustible cigarette smoking among non-smoking youth (aOR = 3.8; $p < 0.0001$)
Chen et al. (2017) [32]	18,392 youth Age 11–18	Cross-Sectional Survey National Study (NYTS)	60.9% of past 30-day vapers reported using flavored e-cigarettes
Dai et al. (2016) [34•]	2017 adolescents Past 30-day vapers Age 11–18	Cross-Sectional Survey National Study (NYTS)	Flavored e-cigarette use was associated with increased intentions to initiate combustible cigarette use among never-smokers (aOR = 5.7; $p < 0.0001$) Flavored e-cigarette use was associated with reduced intentions to quit tobacco use among smokers (aOR = 0.6; $p = .006$)
Dawkins et al. (2013) [42]	1347 adult vapers Age $M(SD) = 43.4 (12.0)$	Online Survey	More combustible cigarette smokers (61%) used tobacco-flavored e-cigarettes than former smokers (51%; $p = 0.012$)
Eiter et al. (2011) [44]	3587 vapers Age $Median(IQR) = 41 (31–50)$ 70% former smokers	Online Survey	Current smokers were more likely to use tobacco-flavored e-cigarettes ($p < 0.01$)
Farsalinos et al. (2013) [45]	4618 adult vapers Age $Median(IQR) = 40 (32–49)$	Online Survey	More current smokers (53.0%) than former smokers (43.1%) used tobacco-flavored e-cigarettes ($p < 0.0001$) More former smokers (30.4%) than current smokers (24.1%) initiated e-cigarette use with sweet-flavored e-cigarettes ($p = 0.009$)
Harrell et al. (2016) [35••]	5482 young adults (age 18–29) 6051 adults nationwide (age ≥ 30) 35 adult vapers Age 18–65	Cross-Sectional Survey Texas Focus Group	Use of tobacco-flavored e-cigarettes was more common among dual users than exclusive e-cigarette users ($p < 0.05$) E-cigarette-only users (vs. dual users) preferred using fruit or sweet/dessert flavors
Kim et al. (2016) [73]	65% smokers 3614 high school students 1166 middle school students HS M age (SD) = 15.6 (1.2) MS M age (SD) = 12.2 (0.9) 379 dual users 268 smokers	Cross-Sectional Survey Connecticut	A greater proportion of current smokers (12.2%) preferred tobacco-flavored e-cigarettes than never-smokers (4.7%) A greater proportion of current smokers (62.0%) preferred menthol-flavored e-cigarettes than never-smokers (52.1%)
Nommemaker et al. (2016) [47]	379 dual users 268 smokers 13 exclusive vapers Age 19+	Cross-Sectional Survey Florida	The absence of flavorings reduced the price exclusive vapers (vs. smokers and dual users) would be willing to pay for e-cigarettes
Patel et al. (2016) [78]	2295 smokers 153 nonsmokers Age 18+	Cross-Sectional Survey Online	Lighter smokers (vs. heavier smokers) expressed a preference for sweet-flavored e-cigarettes
Schmeller et al. (2018) [37]	2123 adult vapers (age 35–54) 415 youth vapers (age 12–17) 80.4% youth between the ages of 15–17 years	Cross-Sectional Survey National Study (PATH)	Youth (vs. adults) were significantly more likely to use fruit-flavored e-cigarettes (OR [95% CI] = 2.11 [1.55, 2.87]) Youth (vs. adults) were significantly less likely to use menthol/mint-flavored e-cigarettes (OR [95% CI] = 0.14 [0.06, 0.32]) Youth (vs. adults) were significantly more likely to report using 1 flavoring compared to tobacco or unflavored e-cigarette (OR [95% CI] = 2.83 [1.99, 4.03]) Youth were more likely to report using 2+ flavorings (OR [95% CI] = 5.26 [3.60, 7.68])
Differences in flavored E-cigarettes use by age Bonhomme et al. (2016) [40]	3434 adult vapers Age 18+	Cross-sectional Survey National Adult Tobacco Survey (NATS)	Younger age was associated with flavored e-cigarette use 85.2% of 18–24 year olds used flavored e-cigarettes 51.8% of 45–64 year olds used flavored e-cigarettes Younger age was associated with flavored e-cigarette use (aOR [95% CI] = 1.28, [1.37, 2.41]; $p < 0.0001$)
Chen et al. (2018) [41]	12,383 young adults Age 18–34	Prospective Survey National Study (PATH)	Younger adults (vs. older adults) emphasized the ability to experiment with multiple flavors as key reasons for e-cigarette use
Eiter (2016) [43]	2807 vapers Age $Median(IQR) = 41 (31–50)$ 80% former smokers	Online Survey	72.9% of youth cited flavorings as a reason for e-cigarette use 57.4% of young adults cited flavorings as a reason for e-cigarette use 47.5% of older adults used tobacco-flavored e-cigarettes at initiation
Harrell et al. (2016) [35••]	3907 youth (age 12–17) 5482 young adults (age 18–29) 6051 adults (age ≥ 30)	Cross-Sectional Survey Texas	21.0% of young adults used tobacco-flavored e-cigarettes at initiation Younger participants (aged 18–34) were more likely to prefer flavored e-cigarettes Older adults (aged 45–65) preferred tobacco-flavored e-cigarettes
Kim et al. (2016) [73]	35 adult vapers Age 18–65 65% smokers	Focus Group	

Table 4 (continued)

Citation	Population	Study design	Major findings
Kong et al. (2015) [14]	5405 middle, high school and college students MS <i>M</i> age (<i>SD</i>) = 12.2 (0.9) HS <i>M</i> age (<i>SD</i>) = 15.6 (1.2) College <i>M</i> age (<i>SD</i>) = 22.1 (5.5) 2295 smokers 153 nonsmokers	Cross-Sectional Survey Focus Groups	High school students (vs. college students) were more likely to cite flavorings as a reason for experimentation with e-cigarettes (47.0 vs. 32.8%; $p < 0.001$)
Patel et al. (2016) [78]	Age 18+ 1443 adult tobacco users	Cross-Sectional Survey Online	Younger e-cigarette users were more likely to cite flavorings as a reason for use
Smith et al. (2016) [49]	Age 18+	Telephone Survey	Younger age (i.e., being 18–24 years old) was associated with increased odds of using flavored tobacco products at initiation
Villanti et al. (2017) [38••]	23,208 adults (age 25–65+) 9112 young adults (age 18–24) 13,651 youth (age 12–17)	Cross-sectional survey PATH Study	Prevalence of current flavored e-cigarette use was higher among youth (31.2%) than young adults (13.6%) and adults (7.0%)
Gender and race differences in flavored E-cigarette use			
Baumann et al. (2015) [79]	944 hospitalized smokers White age: <i>M</i> (<i>SD</i>) = 44.7 (13.2) Black age: <i>M</i> (<i>SD</i>) = 46.8 (12.4)	Cross-sectional survey	There were race differences in flavored e-cigarette use ($p < 0.001$) A higher proportion of Blacks (71%) used menthol-flavored e-cigarettes compared to Whites (34%) More Whites (61%) than Blacks (3%) used tobacco-flavored e-cigarettes
Chen et al. (2018) [41]	55.3% male 12,383 young adults (aged 18–34)	Prospective Survey National Study (PATH)	Female gender was associated with flavored e-cigarette use (aOR [95% CI] = 1.81 [1.33, 2.46]; $p < 0.001$) Black participants (vs. white) were more likely to use flavored e-cigarettes (aOR = 0.64 [0.42, 0.99]; $p = 0.04$)
Dawkins et al. (2013) [42]	1347 vapers Age <i>M</i> (<i>SD</i>) = 43.4 (12.0) 30% female 96% White	Online Survey	Males preferred tobacco-flavored e-cigarettes ($p < 0.001$) More females used sweet-flavored e-cigarettes ($p < 0.001$)
Kisler et al. (2017) [80]	34 vapers Age <i>M</i> (<i>SD</i>) = 41 (18) 56% female 68% White	Focus group	Females (vs. males) mentioned flavor more often and preferred the variety of flavors
Oncken et al. (2016) [81]	20 adult vapers Age <i>M</i> (<i>SD</i>) = 42.2 (9.7) 45% female 70% White	Laboratory study	Significant flavor × sex interaction ($p < .01$) Females (vs. males) rated e-cigarettes as significantly less appealing when using their non-preferred e-cigarette flavor
Patrick et al. (2016) [56]	4066 high school students (8th, 10th, 12th grades)	Cross-Sectional Survey National Study (MTF) Online survey	Significantly more White (38.9%) than Black (31.9%) and Hispanic (29.6%) students reported vaping "Because it tastes good" Significant sex differences in flavored e-cigarette use ($p = 0.009$) 81.2 of males used flavored e-cigarettes vs. 86.1% of females 18.8% of males used tobacco-flavored e-cigarettes vs. 13.9% of females
Piñero et al. (2016) [82]	1815 e-cigarette users <i>M</i> age (<i>SD</i>) = 39.82 (13.10) 37.5% age 30–44 33.2% female 92.1% White	Laboratory study	Females (vs. males) rated the overall sensory effects of menthol higher in the low menthol condition (0.5% menthol) without nicotine
Rosbrook et al. (2016) [71]	32 adult smokers Age 18–45 50% male 81% menthol-smokers 16%–38% vapers	Laboratory study	Males (vs. females) rated irritation/harshness higher in the high-menthol (3.5%) low nicotine condition Females (vs. males) rated irritation/harshness lower at the highest nicotine concentration

Citations are presented in alphabetical order: NYTS, National Youth Tobacco Survey; PATH, Population Assessment of Tobacco and Health Study; NATS, National Adult Tobacco Survey; OR, odds ratio; aOR, adjusted odds ratio; Vaper, E-Cigarette user

Black (31.9%) and Hispanic (29.6%) students reported vaping, “because it tastes good” [56]. A prospective study of young adults aged 18–34 found that Black participants were less likely (adjusted OR [95% CI]=0.64 [0.42, 0.99]) than White participants to use flavored e-cigarettes [41]. A cross-sectional study of 944 hospitalized smokers aged 19–80 years old (55.3% male, 43.0% Black) found that Black participants (71%) used menthol-flavored e-cigarettes at higher rates than White participants (34%), whereas more White (61%) than Black participants (3%) used tobacco-flavored e-cigarettes [79].

Discussion

This review demonstrates that flavored e-cigarettes are commonly used by adolescent and young adult vapers at e-cigarette initiation and during regular use following initiation. Qualitative and experimental evidence indicate that flavored e-cigarettes are appealing due to their pleasurable sensory qualities, which may suppress the aversive sensory effects of nicotine. Epidemiological evidence suggests that the prevalence of flavored e-cigarette use may differ by age and smoking status, with older adults and smokers using flavored e-cigarettes at lower rates than youth and nonsmokers.

The chemosensory science literature demonstrates that children and adolescents (vs. adults) have a strong preference for sweet flavorings in general [6•], and tobacco industry documents have found that adolescents and young adults are particularly susceptible to flavored tobacco products [3, 4]. Observational evidence suggests that restricting the availability of flavored combustible cigarettes in the USA may have reduced youth tobacco use, of both flavored and unflavored products [83••]. Given evidence that (a) youth perceive flavored e-cigarettes to be less harmful than tobacco-flavored e-cigarettes; (b) flavored e-cigarettes encourage experimentation with e-cigarettes and may maintain use following initiation; and (c) flavored e-cigarette use may increase risk of combustible tobacco product use, flavored e-cigarettes may pose risks to the public health of youth.

Qualitative reports and observational evidence suggest that flavored e-cigarettes (vs. tobacco flavors) may aid adult smokers in smoking reduction and cessation efforts [75, 76••]. However, there is only one extant smoking reduction trial that assessed the efficacy of flavored e-cigarettes to date [68••]. More clinical, laboratory, and epidemiological research is needed to determine whether flavored e-cigarettes, compared to tobacco flavors, can help adult smokers quit or reduce smoking.

This review extends previous research on flavored tobacco products by focusing specifically on flavored e-cigarettes. By synthesizing the extant observational and

experimental data on flavored e-cigarettes, this review highlights the growing prevalence of flavored e-cigarette use among youth and adults and identifies mechanisms through which flavorings enhance the appeal of e-cigarettes. Additionally, the examination of interindividual differences (e.g., age, smoking status, gender, race) suggests that the appeal of flavored e-cigarettes may vary in different segments of the population.

In several places throughout this review, we have identified gaps in the literature. A number of the studies did not distinguish between sweet, menthol, and other flavorings; thus, it was not possible to assess the ways in which specific flavorings differ from one another and may affect e-cigarette use. While experimental studies have examined the appeal of sweet-flavored e-cigarettes in adult and young adult populations, it is unknown if flavorings have the same effects among e-cigarette-naïve adolescents. Few prospective studies have examined trajectories of flavored e-cigarette use over time, and longitudinal data is needed to understand the impact of flavorings on developmental patterns of e-cigarette use as well as progression to or reduction of combustible tobacco product use.

Strengths of the review include the integration of epidemiological and experimental evidence and focus on specific mechanisms through which flavorings enhance e-cigarette product appeal. This review did not include studies conducted solely outside the USA, non-English language articles or studies that did not involve human subjects (e.g., e-liquid toxicology assays, analyses of social media posts, studies focused on marketing and advertising). Additionally, while we included only articles from peer-reviewed journals, we did not assess individual study quality.

Conclusions

The majority of adolescent and young adult vapers use flavored e-cigarettes, while older adults and combustible cigarette smokers may use flavored e-cigarettes at lower rates than youth and nonsmokers. Additional data is needed to determine whether use of flavored (vs. unflavored) e-cigarettes may improve cessation outcomes among adult smokers. Systematic approaches are necessary to fully characterize the public health impact of flavored e-cigarettes and to inform evidence-based regulatory policies.

Compliance with Ethical Standards

Conflict of Interest AL, KS, and JBT declare no conflicts of interest. NG accepted a job with JUUL Labs on February 10, 2019, and did not contribute to the paper after that date.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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