



## U.S. digital tobacco marketing and youth: A narrative review

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### ABSTRACT

We describe findings from peer-reviewed articles on digital tobacco marketing (DTM) using U.S. data related to youth, including research that examines use of age restrictions, DTM exposure and engagement, and associated tobacco use. We searched PubMed, EMBASE, Web of Science, and EBSCOhost in May 2019 and May 2020 for published English language peer-reviewed articles examining DTM that were published from January 2016 to May 2020. Inclusion coding occurred in three stages. The first search identified 519 articles; 167 were coded for inclusion. The second search identified 189 articles; 67 were coded for inclusion. Two coders then assessed whether the included articles mentioned youth (age 18 and younger) or age restrictions in the method and results sections of the full text. Ultimately, 47 articles were included in this review. A codebook was developed and tested through training. Each article was coded for age restrictions, youth exposure to DTM, youth engagement with DTM, and youth tobacco use associated with DTM exposure or engagement. The studies reviewed indicate that DTM on social media was infrequently age-restricted and the stringency of age restriction varied by tobacco product, site owner, and channel. Youth reported being exposed to DTM frequently via the Internet. While youth reported less frequently engaging with DTM compared to being exposed, engagement increased over time. DTM exposure and engagement were associated with tobacco product use. The studies reviewed document an association between DTM exposure and engagement and future tobacco use; thus, DTM may be contributing to the youth tobacco epidemic.

Over the past fifty years, legislation and legal agreements have limited where and how tobacco companies can market their products in the United States. In 1971, the Public Health Cigarette Smoking Act banned cigarette advertising on TV and radio (Act, 1970); the 1998 Master Settlement Agreement restricted the use of cartoons, tobacco brand sponsorship of sporting events and concerts, and marketing practices that target individuals under the age of 18 (National Association of Attorneys General, 2000); and the 2009 Family Smoking Prevention and Tobacco Control Act further restricted tobacco brand sponsorships and tobacco branding of non-tobacco items (US Department of Health and Human Services, 2009). In August 2016, the “Deeming Rule” extended FDA’s tobacco product authorities to all products that meet the statutory definition of “tobacco product” under section 201(rr) of the Federal Food, Drug, and Cosmetic Act and required the display of health warnings on all covered tobacco products and their advertisements. Advertisements addressed by the “Deeming Rule” include those appearing on “Internet Web pages, television,

electronic mail correspondence, and also include those communicated via mobile telephone, smartphone, microblog, social media Web site, or other communication tool; Web sites, applications, or other programs that allow for the sharing of audio, video, or photography files; video and audio promotions; and items not subject to the sale or distribution ban in Section 1140.34” (US Department of Health and Human Services, 2016). The Children’s Online Privacy Protection Act of 1998 restricts access to social media platforms available for paid digital advertising to users who are at minimum aged 13 (Commission, 1998). However, no federal or state laws specifically restrict digital tobacco marketing.

Digital tobacco marketing (DTM) refers to the use of digital platforms (such as websites, social media, email, digital TV and radio) to market tobacco products to consumers. DTM poses a particular risk to youth ages eighteen and younger because most youth use digital channels. In 2018, approximately half (45 %) of U.S. teens aged 13 to 17 reported being online on a “near-constant basis” and most (85 %) used at least one social media platform (Anderson and Jiang, 2018). In 2019, most

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leading electronic nicotine delivery systems (ENDS), hookah, and cigar brands had pages on at least two social media platforms and one-third of smokeless tobacco brands had pages on at least one social media platform (O'Brien et al., 2020). Given the high rates of tobacco marketing on digital channels and frequency with which youth report being online, youth may therefore be particularly likely to be exposed to tobacco product marketing on digital channels. Additionally, digital channels allow for various forms of engagement. For example, youth may engage with DTM by liking or following a tobacco brand on a social media site (Soneji et al., 2017), signing up for email alerts about tobacco products (Choi et al., 2019), or writing, responding to, or re-blogging posts about tobacco products on social media (Hebert et al., 2017). Opportunities for two-way engagement such as these distinguish digital marketing from traditional marketing (Freeman, 2012; Ribisl, 2003). Tobacco products may also be more accessible to youth on digital channels where tobacco products may be sold directly to site users and the rigor of age restriction varies. For example, age verification is a more rigorous form of age restriction that requires site users to provide identification information verified by a third party; less rigorous age restriction may require site users to simply click a button on a pop-up window to affirm they are of legal age to purchase tobacco products. Variance in age-restriction rigor on digital channels may make tobacco products more accessible to youth.

Ultimately, DTM may encourage youth tobacco use by providing access to tobacco products and stimulating demand through marketing messages. To better understand tobacco product accessibility and how DTM may stimulate youth tobacco demand, we reviewed articles that document DTM age restrictions, DTM exposure, and DTM engagement. This review does not represent current DTM practices, which have been impacted by recent changes in the regulatory landscape. Instead, this review summarizes youth DTM research published from January 2016 to May 2020 because at that time the tobacco marketplace was changing rapidly with ENDS digital marketing increasing substantially in 2016. This smaller time frame also allowed us to focus on youth interaction with DTM without the complexities of changing technologies and available marketing platforms.

## 1. Methods

### 1.1. Data sources

We conducted an initial search (May 2019) and an updated search (May 2020) of four databases (PubMed, EMBASE, EBSCOhost, and Web of Science) for published articles examining DTM. First, we conducted a search in May 2019 for articles published between January 2016 and May 2019. The search string (see Table 1) included terms related to marketing, digital media, and tobacco. We conducted a second search in May 2020 to include more recent articles published between June 2019 and May 2020 using the same databases and search string. While the articles were published between January 2016 and May 2020, the data used in the studies was collected from 2014 to 2019.

### 1.2. Study selection

Inclusion coding occurred for two searches. For both searches, articles were excluded because they (a) were not about tobacco marketing, (b) were not about digital marketing (studies could include information about tobacco advertising in other media in addition to digital media, as long as data for digital media and other media were not aggregated), (c) only included data from outside the United States, or (d) were not written in English. The first search identified 519 articles after removing duplicates. After screening articles based on titles/abstracts, four reviewers independently coded the full text of 167 articles for inclusion, double coding 10 % of the articles. Interrater reliability for inclusion coding was acceptable (ICC = 0.83). One-hundred seven articles were included from the first search. The second search included articles

**Table 1**  
Search Terms and Criteria.

Category	Specific terms	Criteria
Marketing terms (TITLE, KEYWORD, ABSTRACT, "AND")	Marketing, advertising, ad, promotion, commercial, coupon, brand(ing), discount, rewards program, sale(s), selling, purchasing, buying, ordering, touchpoints, customer relationship management, conversion, native content, product reviews, media, direct-to-consumer, product placement, concerts, artist	Tobacco brand digital marketing in US, English language
Digital terms (TITLE, KEYWORD, ABSTRACT, "AND")	Social media, Facebook, Instagram, Twitter, Tweet, YouTube, Snapchat, Pinterest, Tumblr, Reddit, Quora, Yelp, WhatsApp, private groups, discussion group, forums, followers, influencers, brand ambassadors, third-party, games, apps, applications, smartphones, devices, digital, internet, online, mobile, website, webpage, email, blog, vlog, push update(s), e-newsletter, e-subscription, e-marketing, text message, SMS, chat, video, repost, hashtag, impressions, streaming, gaming, meme	
Tobacco terms (TITLE ONLY)	Tobacco, nicotine, cigarette, roll-your-own, E-CIGARETTES, electronic cigarette, electronic nicotine delivery systems, E-CIGARETTES, electronic vaping system, mod, cigalike, ego, tank, e-hookah, e-liquid, e-juice, nicotine salts, vaping, vape, smokeless tobacco, dip, chew, snuff, snus, cigar, cigarillo, hookah, waterpipe, narghile, shisha, pipe	

published between June 2019 and May 2020 and identified an additional 189 articles after de-duplication. After screening articles based on titles/abstracts, four reviewers independently coded the full text of 67 articles for inclusion, double coding 10 % of the articles. Interrater reliability for inclusion coding was acceptable (ICC = 0.72). Fifty articles were included from the second search, resulting in a total of 157 articles from searches one and two. Discrepancies for study selection were resolved through discussions among the coders.

Two coders conducted a third round of coding to assess youth relevance of the 157 articles. Youth-relevant articles (a) described a youth (18 years or younger) focus in the methods section (e.g., youth sample) or (b) focused on the use of age restrictions on DTM in the methods and results sections. Ultimately, 47 articles were included in this review (see Supplemental Figure 1: PRISMA Table).

### 1.3. Theme identification

We developed a codebook and tested it through several training phases. Discrepancies were resolved through discussions among the coders. Almost all themes were coded for presence or absence. Only age restriction was coded depending on the level of information the article provided. All themes were identified in the methods and results sections of the included articles.

#### 1.3.1. Age restrictions

Articles were coded as documenting age restriction if they (a) stated whether youth were restricted from viewing DTM or (b) reported data on DTM age restrictions.

### 1.3.2. Age restrictions on sites that give or sell tobacco products

Articles that were coded for age restriction were further coded to determine whether they documented tobacco companies giving away tobacco products or selling tobacco products.

### 1.3.3. Exposure

Articles were coded as documenting DTM exposure if they asked youth to self-assess their viewing of DTM (e.g., survey results reporting the percent of youth who stated that they visited tobacco websites).

### 1.3.4. Engagement

Articles were coded as documenting DTM engagement if they asked youth to self-assess their interaction with DTM (e.g., survey results reporting the percent of youth who stated that they have ever clicked on a tobacco ad online).

### 1.3.5. Tobacco use

Articles were coded as documenting tobacco use if they measured youth tobacco use (e.g., survey results reporting the percent of youth who stated that they use e-cigarettes).

## 2. Results

Forty-seven studies published between January 2016 and May 2020 were included in the review. Table 2 lists the number of articles that addressed each topic.

### 2.1. DTM age restrictions

Twenty-four articles examined DTM age restrictions: 18 reported data on age restrictions (O'Brien et al., 2020; Asfar et al., 2019; Chen et al., 2020; Cuomo et al., 2016; Escobedo et al., 2018; Hsu et al., 2018; Huang et al., 2016; Jackler et al., 2019; Kostygina et al., 2016; Laestadius et al., 2019; Laestadius et al., 2020; Moran et al., 2019; Nguyen et al., 2020; O'Brien et al., 2019; Sears et al., 2017; Seidenberg et al., 2016; Soneji et al., 2016; Timberlake et al., 2016) and six discussed whether DTM was age-restricted (Ganz et al., 2018; Hoek and Freeman, 2019; Kong et al., 2019; McDaniel et al., 2016; Soule et al., 2019; Unger and Bartsch, 2018). These studies documented that at the time of data collection, ENDSs, hookah, and cigar websites and social media pages were less frequently and less rigorously age-restricted than traditional tobacco (i.e., cigarette and smokeless tobacco) websites and social media pages.

Eleven articles examined DTM age restrictions on social media. Three articles examined age restriction data collected prior to the deeming rule from YouTube (Huang et al., 2016; Sears et al., 2017; Kong et al., 2019) and Twitter (Kostygina et al., 2016). The remaining articles examined age restriction data collected post-deeming from Instagram (Laestadius et al., 2019; Laestadius et al., 2020), Facebook (Jackler et al., 2019), Yelp (Asfar et al., 2019), and multiple social media platforms (O'Brien et al., 2020; Ganz et al., 2018; Hoek and Freeman, 2019). Studies documented infrequent use of age restrictions on brand-

**Table 2**  
Number of Articles by Topic.

Topic	Number of Articles
Age Restrictions	24
Age Restrictions: Give	2
Age Restrictions: Sell	10
Youth DTM Exposure	18
Youth DTM Exposure and Tobacco Use	18
Youth DTM Engagement	8
Youth DTM Engagement and Tobacco Use	8

*Note.* The numbers do not add to 47 because some articles addressed only one topic, while other studies addressed multiple topics (e.g., measured youth DTM exposure and youth tobacco use).

sponsored or industry-tied (e.g., social media influencer) Facebook pages (O'Brien et al., 2020; Jackler et al., 2019), Instagram pages (O'Brien et al., 2020; Laestadius et al., 2020), Twitter pages (O'Brien et al., 2020), and YouTube channels (O'Brien et al., 2020; Sears et al., 2017). For example, fewer than half (44 %; n = 48) of 108 "leading tobacco brands" Facebook pages excluded those younger than age 18 from viewing tobacco promotions in 2017 (Jackler et al., 2019). Similarly, few leading tobacco brands' social media pages examined in 2019 used any age restrictions beyond the minimum age of 13 required to access the platforms: no Twitter pages, few YouTube (2.5 %) and Instagram (5.7 %) pages, and one-third of Facebook pages were age-restricted (O'Brien et al., 2020). Influencer marketing of tobacco products on social media was also rarely age-restricted (Kostygina et al., 2016; Laestadius et al., 2020).

Fourteen articles examined DTM age restrictions on owned websites or paid advertising: seven examined manufacturer, retailer, or brand websites pre-deeming (Cuomo et al., 2016; Escobedo et al., 2018; Seidenberg et al., 2016; Soneji et al., 2016; Timberlake et al., 2016; McDaniel et al., 2016; Unger and Bartsch, 2018); six examined manufacturer, retailer, or brand websites post-deeming (Chen et al., 2020; Hsu et al., 2018; Nguyen et al., 2020; O'Brien et al., 2019; Ganz et al., 2018; Soule et al., 2019). One article examined paid digital advertising that ran any time during 2016 and so captured data both before and after the "Deeming Rule" (Moran et al., 2019). Almost all cigarette and smokeless tobacco manufacturer websites examined in the reviewed studies required age verification for site entry (Escobedo et al., 2018; O'Brien et al., 2019; Timberlake et al., 2016). Research reviewed found that compared to cigarette and smokeless tobacco websites, fewer ENDS (Cuomo et al., 2016; Escobedo et al., 2018; Nguyen et al., 2020; O'Brien et al., 2019; Soneji et al., 2016), hookah (Escobedo et al., 2018; O'Brien et al., 2019), and cigar websites (Escobedo et al., 2018; O'Brien et al., 2019) required rigorous age-verification for access (i.e., required information that could be verified by third-parties), instead using less rigorous age restrictions (i.e., age affirmation) or failing to age-restrict. Evidence also suggests that age restriction stringency varies depending on the type of company that owns the website. In an investigation of ENDS brand websites in 2016–2017, 83 % of websites "owned by major tobacco companies" featured an "age pop-up window" that asked visitors to self-report their age or affirm they met a minimum age threshold compared to only 50.2 % of Internet-only brands (i.e., brands that were only sold online) and 60.5 % of vape shop brands (i.e., operated their own physical vape shop) that included an age pop-up window as compared to no age pop-up window (Hsu et al., 2018).

### 2.2. Age restrictions on sites selling products

Lack of age restriction is particularly problematic when tobacco products are sold via DTM because it indicates that youth can access products. There was limited evidence in the studies reviewed of products being given away on DTM and the two articles that did provide evidence of product giveaways used data collected pre-deeming rule (i.e., before August 2016). These articles (Huang et al., 2016; Laestadius et al., 2019), documented contests to win e-liquids on Instagram (Laestadius et al., 2019) and free trials in ENDS YouTube videos (Huang et al., 2016). Ten articles (O'Brien et al., 2020; Cuomo et al., 2016; Hsu et al., 2018; Jackler et al., 2019; Nguyen et al., 2020; O'Brien et al., 2019; Sears et al., 2017; Seidenberg et al., 2016; Timberlake et al., 2016; Soule et al., 2019) discussed age restrictions on DTM where tobacco products are sold, four of which used data collected pre-deeming rule (Cuomo et al., 2016; Sears et al., 2017; Seidenberg et al., 2016; Timberlake et al., 2016). Studies documented that ENDS and hookah websites were not only infrequently and less rigorously age-restricted, but they also sold tobacco products. For example, 50 % of hookah and 25 % of ENDS smartphone-optimized mobile websites investigated that sold tobacco products did not require age verification to purchase tobacco products online in 2017 (O'Brien et al., 2019).

### 2.3. Youth exposure to DTM

Eighteen articles assessed youth DTM exposure (Hebert et al., 2017; Unger and Bartsch, 2018; Camenga et al., 2018; Chen et al., 2020; Chen-Sankey et al., 2019; Strong et al., 2019; Cruz et al., 2019; Dai and Hao, 2016; Loukas et al., 2019; Mantey et al., 2018; Mantey et al., 2016; Marion et al., 2020; Nicksic et al., 2017; Roberts et al., 2019; Rose et al., 2018; Simon et al., 2018; Singh et al., 2016; Singh et al., 2016). See Table 3 for study design characteristics.

DTM exposure refers to passively viewing marketing materials. The percentage of youth who reported DTM exposure varied depending upon who was surveyed (e.g., tobacco use status, age, location), when the survey occurred, and how exposure was assessed (e.g., channels, recall period, tobacco products). For example, ecological momentary assessments (EMAs) lasting 10 days each found that 25 % of the adolescent (aged 11–16) sample who completed the EMA during 2016–2017 had been exposed at least once to tobacco marketing on the Internet (Roberts et al., 2019). The authors did not report whether exposure varied before and after the deeming rule. A 2014–2015 survey documented that 52.5 % of youth in sixth, eighth, and 10th grade who were sampled reported past 30-day exposure to a tobacco product-related post on a social media site (Hebert et al., 2017). A 2015–2016 nationally representative survey of youth found that 56.5 % of youth never tobacco users reported past-month ENDS marketing exposure on web sites or social media (Chen-Sankey et al., 2019). ENDS DTM exposure was most frequently assessed. Approximately 40 % of youth reported exposure to ENDS marketing on the Internet (Strong et al.,

**Table 3**  
DTM Exposure Study Characteristics (n = 18).

	Number of Studies Assessing Exposure (n = 18/47) N (%)	Citations
<i>Data Collection Source/Method</i>		
National Youth Tobacco Survey	6 (33 %)	(36, 38–40, 45, 46)
Population Assessment of Tobacco and Health	3 (17 %)	(30, 33, 43)
Texas Adolescent Tobacco and Marketing Surveillance System	3 (17 %)	(5, 37, 41)
Survey of Connecticut Youth	2 (11 %)	(31, 44)
International Tobacco Control Policy Evaluation Project Youth Tobacco and Vaping Survey	1 (6 %)	(34)
Southern California Children's Health Study	1 (6 %)	(35)
Ecological Momentary Assessment (EMA)	1 (6 %)	(42)
Focus Group	1 (6 %)	(32)
<i>Product</i>		
ENDSs	11 (61 %)	(31–34, 36, 37, 39, 41, 44–46)
Multiple tobacco products <sup>a</sup>	4 (22 %)	(30, 35, 38, 40)
General tobacco <sup>b</sup>	3 (17 %)	(5, 42, 43)
<i>Time Period</i>		
Multiple times over 10 days	1 (6 %)	(42)
Past 30 days	4 (22 %)	(5, 33, 34, 37)
Past 6 months	2 (11 %)	(30, 43)
Recently	1 (6 %)	(31)
No time specified	10 (56 %)	(32, 35, 36, 38–41, 44–46)
<i>Data Collection</i>		
Pre-Deeming Rule	12	(5, 9, 30, 31, 36, 38, 39, 41, 43–46)
Post-Deeming Rule	3	(34, 37, 40)
Pre- and Post-Deeming Rule	3	(33, 35, 42)

<sup>a</sup> “Multiple tobacco products” refers to studies that asked participants about exposure to advertising for two or more tobacco products.

<sup>b</sup> “General tobacco” refers to studies that asked participants about exposure to “tobacco products” without specifying any specific product.

2019; Loukas et al., 2019; Mantey et al., 2016; Nicksic et al., 2017; Singh et al., 2016; Singh et al., 2016).

### 2.4. Youth exposure to DTM and tobacco use

Almost all studies that assessed youth DTM exposure also assessed youth tobacco use (Hebert et al., 2017; Unger and Bartsch, 2018; Camenga et al., 2018; Chen et al., 2020; Chen-Sankey et al., 2019; Strong et al., 2019; Cruz et al., 2019; Dai and Hao, 2016; Loukas et al., 2019; Mantey et al., 2018; Mantey et al., 2016; Marion et al., 2020; Nicksic et al., 2017; Roberts et al., 2019; Rose et al., 2018; Simon et al., 2018; Singh et al., 2016). These studies documented statistically significant positive associations between youth DTM exposure and tobacco use. Ten studies examined DTM exposure and tobacco use cross-sectionally (Hebert et al., 2017; Unger and Bartsch, 2018; Strong et al., 2019; Dai and Hao, 2016; Mantey et al., 2018; Mantey et al., 2016; Marion et al., 2020; Roberts et al., 2019; Simon et al., 2018; Singh et al., 2016). All cross-sectional studies demonstrated a statistically significant positive association between DTM exposure and susceptibility to (Hebert et al., 2017; Unger and Bartsch, 2018; Mantey et al., 2016) or use of (Hebert et al., 2017; Unger and Bartsch, 2018; Strong et al., 2019; Dai and Hao, 2016; Mantey et al., 2018; Mantey et al., 2016; Marion et al., 2020; Roberts et al., 2019; Simon et al., 2018; Singh et al., 2016) tobacco products. For example, among middle and high school students under age 18, dual users of ENDS and cigarettes were significantly more likely to report exposure to online “pro-tobacco” marketing in the past 30 days (Marion et al., 2020).

Six studies examined DTM exposure and tobacco use longitudinally (Camenga et al., 2018; Chen-Sankey et al., 2019; Cruz et al., 2019; Loukas et al., 2019; Nicksic et al., 2017; Rose et al., 2018). Five studies documented statistically significant positive associations between DTM exposure and subsequent tobacco use (Camenga et al., 2018; Chen-Sankey et al., 2019; Cruz et al., 2019; Nicksic et al., 2017; Rose et al., 2018). For example, 11th and 12th grade students who reported frequent exposure to cigarette marketing on the Internet were significantly more likely than students who reported no exposure to cigarette marketing on the Internet to initiate cigarette use 16 months later (OR = 2.98; 95 % CI = 1.56, 5.66) (Cruz et al., 2019). Similarly, never ENDS users who reported frequent exposure to ENDS Internet marketing were more likely to initiate ENDS use 16 months later (OR = 2.39; 95 % CI = 1.46, 3.89) than never ENDS users who reported no exposure to ENDS Internet marketing (Cruz et al., 2019). Youth respondents to a nationally representative survey had greater odds (aOR = 1.53; 95 % CI = 1.07–2.17) of ENDS experimentation in 2015–2016 if they reported exposure to ENDS marketing on websites or social media in 2014–2015 (Chen-Sankey et al., 2019). One longitudinal study of Texas youth ages 12–17 did not find a statistically significant association between ENDS Internet marketing exposure and ENDS initiation 2.5 years later (Loukas et al., 2019). This disparate finding may be due to the comparatively longer time between measurement of marketing exposure and tobacco initiation (i.e., 2.5 years (Loukas et al., 2019) vs 1.3 years (Cruz et al., 2019) vs 1 year (Chen-Sankey et al., 2019).

The association between DTM exposure and tobacco use is stronger among youth who report greater frequency of DTM exposure (Strong et al., 2019; Dai and Hao, 2016; Roberts et al., 2019; Singh et al., 2016) and exposure to DTM through multiple channels (Chen-Sankey et al., 2019; Dai and Hao, 2016; Mantey et al., 2018; Mantey et al., 2016; Simon et al., 2018). Evidence also suggests that exposure to DTM for one product type is associated with use of other tobacco product types (Cruz et al., 2019).

### 2.5. Youth engagement with DTM

Eight articles assessed youth DTM engagement (Soneji et al., 2017; Choi et al., 2019; Hebert et al., 2017; Chen et al., 2020; Soneji et al., 2019; Soneji et al., 2019; Soneji et al., 2018; Soneji et al., 2018). See

**Table 4**  
DTM Engagement Study Characteristics (n = 8).

	Number of Studies Assessing Engagement (n = 8/47) N (%)	Citations
<i>Data Collection Source/Method</i>		
Population Assessment of Tobacco and Health	5 (63 %)	(3, 4, 48–50)
Texas Adolescent Tobacco and Marketing Surveillance System	1 (13 %)	(5)
Online Survey	1 (13 %)	(47)
Focus Groups	1 (13 %)	(32)
<i>Product</i>		
ENDSs	1 (13 %)	(32)
Multiple tobacco products <sup>a</sup>	6 (75 %)	(3–5, 48–50)
<i>Time Period</i>		
General tobacco <sup>b</sup>	1 (13 %)	(47)
Past 30 days	1 (13 %)	(5)
Past 6 months	5 (63 %)	(3, 4, 47, 49, 50)
Multiple times specified	1 (13 %)	(48)
No time specified	1 (13 %)	(32)
<i>Data Collection</i>		
Pre-Deeming Rule	7 (87 %)	(3–5, 32, 48–50)
Post-Deeming Rule	1 (13 %)	(47)

<sup>a</sup> “Multiple tobacco products” refers to studies that asked participants about exposure to advertising for two or more tobacco products.

<sup>b</sup> “General tobacco” refers to studies that asked participants about exposure to “tobacco products” without specifying any specific product.

Table 4 for study characteristics.

DTM engagement refers to interaction with DTM. Most studies examined DTM engagement across multiple tobacco products (Soneji et al., 2017; Choi et al., 2019; Hebert et al., 2017; Soneji et al., 2019; Soneji et al., 2018; Soneji et al., 2018). Two studies examined engagement longitudinally and demonstrated an increase in youth DTM engagement over time with data collected prior to the Deeming Rule (Soneji et al., 2019; Soneji et al., 2018). For example, in a nationally representative longitudinal study, estimated prevalence of engaging with at least one form of online tobacco marketing increased from 8.7 % of adolescents in 2013–2014 to 20.9 % of adolescents in 2014–2015 (Soneji et al., 2018). Engagement with all forms of DTM assessed increased significantly over time from 2013–2014 to 2014–2015, the most recent longitudinal study to assess rates of engagement over time (Soneji et al., 2018). Most adolescents who engaged with DTM did so with a single form of engagement (Soneji et al., 2019). Two separate analyses of nationally representative data from 2013 to 2015 revealed that signing up for email alerts, reading articles online, or watching videos online about tobacco products was the most prevalent form of DTM engagement among adolescents (Soneji et al., 2018; Soneji et al., 2018). One longitudinal study documented a significant association between DTM engagement at baseline and subsequent higher engagement at follow-up (Soneji et al., 2019).

## 2.6. Youth DTM engagement and tobacco use

All studies that assessed youth DTM engagement also assessed youth tobacco use (Soneji et al., 2017; Choi et al., 2019; Hebert et al., 2017; Chen et al., 2020; Soneji et al., 2019; Soneji et al., 2019; Soneji et al., 2018; Soneji et al., 2018). Four studies examined DTM engagement and tobacco use cross-sectionally (Soneji et al., 2017; Hebert et al., 2017; Chen et al., 2020; Soneji et al., 2019). Three of these studies demonstrated a significant positive association between DTM engagement and susceptibility to and use of tobacco products (Soneji et al., 2017; Hebert et al., 2017; Soneji et al., 2019). For example, youth who were susceptible to ENDS and combustible tobacco product use were significantly more likely to report writing or responding to tobacco-related social

media than those who were not susceptible or susceptible to using only one product type (Hebert et al., 2017). The fourth study did not assess whether use was associated with engagement; instead, tobacco use among focus group participants was provided only as demographic information (Chen et al., 2020).

Two longitudinal studies examined and documented statistically significant associations between DTM engagement and subsequent tobacco product use (Choi et al., 2019; Soneji et al., 2018). Engagement with a least one form of online tobacco marketing was positively associated with multiple tobacco use behaviors, including initiating tobacco use, increasing frequency of tobacco use, and progressing to poly product use (Soneji et al., 2018). Furthermore, baseline past-year tobacco product users who engaged with DTM had significantly lower odds of all tobacco product cessation than their counterparts who did not engage with DTM (Soneji et al., 2018). The association between DTM engagement and tobacco use was stronger for youth who engaged with DTM in multiple ways (Choi et al., 2019).

## 3. Discussion

To our knowledge, this is the first review of peer-reviewed research on youth access, exposure to, and engagement with DTM and associated tobacco use. Research from the early 2000 s posited that DTM may affect youth tobacco use by providing access to tobacco products and stimulating demand (Ribisl, 2003). Indeed, research using data from 2014 to 2019 and reviewed here indicates that, during that time, tobacco products were accessible via the Internet due to lax or absent age restrictions, approximately half of youth surveyed reported DTM exposure, and a small but increasing percentage of youth reported engaging with DTM.

ENDS, hookah, and cigar websites were less frequently and less rigorously age-restricted than cigarette and smokeless tobacco websites (O'Brien et al., 2019). Compared to these websites owned by tobacco companies, DTM on social media was even less frequently age-restricted (Jackler et al., 2019; Sears et al., 2017; Kong et al., 2019). While social media platforms YouTube (YouTube Official Blog), Facebook, and Instagram (Azad, 2019) prohibit paid tobacco advertising, they allowed companies to maintain brand pages, promote products through influencers, and include links to purchase tobacco online (Myers, 2019; Digitale, 2020). The lack of rigorous age restrictions on DTM identified in this review indicates that youth were able to access tobacco products.

The prevalence of youth DTM exposure and engagement varied depending upon the assessment measures used in the individual studies. Overall, the studies reviewed documented that approximately half of youth reported DTM exposure, which was significantly positively associated with tobacco use. Though less frequent than exposure, studies reviewed documented an increase in youth DTM engagement over time. As with exposure, DTM engagement was positively associated with tobacco use.

The studies reviewed assessed DTM exposure and engagement using self-report measures (i.e., surveys). Self-report measures embedded in surveys allow for collection of demographic characteristics and tobacco use status. However, they are also resource-intensive and subject to recall bias. Participants were often asked to recall exposure and engagement over long periods of time, usually one to six months. Exposure recalled over a long period often correlates poorly with real-time exposure measures, like those collected via EMA (Roberts et al., 2019). Self-reported measures of engagement likely suffer from the same recall issues. Few studies examined frequency of exposure or engagement, instead using dichotomous yes/no measures that are unable to capture dose–response relationships. Exposure measures also often asked about viewing DTM on broad channels (e.g., “on the Internet”) or specific platforms (e.g., “on YouTube”). Both approaches likely fail to capture some ways in which youth are exposed to DTM (e.g., unique social media platforms, videogames, “over the top”/streaming media like Hulu) and underreport exposure. Engagement measures often

aggregate across tobacco products and do not specify a channel of engagement. These measurement limitations may result in over- or under-estimation of exposure and engagement. Methods like EMA may shed more light on exposure and engagement prevalence.

Though the studies reviewed encompass several DTM channels, the digital space is dynamic, and new platforms, especially social media platforms, are frequently introduced. We reviewed studies assessing DTM exposure and engagement on Facebook, Instagram, Twitter, Yelp, and YouTube but other social media platforms were not documented in the studies reviewed. For example, TikTok is a social media platform for individuals age 12 and older that has 100 million monthly active U.S. users, a third of whom are teens (Perez, 2021). While the platform has some privacy settings, ENDS-related content is reported to be easily accessible and highly viewed (Perez, 2021). Influencer content is also an evolving concern. Research suggests that influencer content is rarely age-restricted (Kostygina et al., 2016; Laestadius et al., 2020). Despite guidance from the Federal Trade Commission that influencers are responsible for disclosing any connections they have with brands they are endorsing (Commission, 2019), influencers may not disclose that they are paid promoters or may do so in a way that is difficult to see and understand. Influencers may also have a high proportion of youth followers who would be exposed to their marketing of tobacco products. Additionally, it can be difficult to determine whether a post is generated by an influencer who received compensation or simply a consumer's organic social media post (i.e., individual's posts that they do not get compensated for). Non-influencer or non-advertiser social media posts are generally outside of the scope of FDA authority, though brands may be responsible for consumer reviews on their pages that may rise to the level of a violation. These emerging issues exemplify the importance of more efficient real-time reports of DTM across channels and promoters.

Review findings should be considered in light of limitations. First, the regulatory landscape for products discussed in this literature review has changed drastically over the past few years. Many of the articles reviewed used data that predate FDA's "Deeming Rule" (regulation that extends FDA's jurisdiction to all tobacco products) (US Department of Health and Human Services, 2016) and FDA's Tobacco 21 law (regulation that raised the federal minimum age for sale of tobacco products from 18 to 21 years of age). All of the articles reviewed used data that predate FDA's final Enforcement Priorities for Electronic Nicotine Delivery Systems and Other Deemed Products on the Market Without Premarket Authorization guidance, issued in April 2020, which states that FDA will prioritize its enforcement to focus on ENDS products whose marketing is likely to promote use by minors (Food and Drug Administration, 2020). All of the articles reviewed used data that predate the March 27, 2021, amendment to the Preventing All Cigarette Trafficking Act, which includes ENDS and bans the U.S. Postal Services from mailing ENDS and smokeless tobacco products ([63]). Still, reviewing existing youth DTM research provides important context and may point to additional topics that are not addressed in existing regulations. Second, as with any systematic review, we may have missed relevant articles that were not identified with our search terms. Third, we did not assess studies' methodological rigor; the goal of our review was to provide a descriptive overview of published literature about DTM age restrictions, youth exposure, and youth engagement with DTM.

#### 4. Conclusions

Our review of peer-reviewed research that used data collected from 2014 to 2019 indicates that DTM on social media was rarely age-restricted during that time and that ENDS, hookah, and cigar websites used less stringent age restrictions than cigarette and smokeless tobacco websites. Though fewer youth reported engaging with DTM compared to exposure, the percentage of youth engaging with DTM was increasing over time. DTM exposure and engagement are associated with future tobacco use; thus, DTM may contribute to youth tobacco use.

#### Declaration of Competing Interest

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

#### Data availability

Data will be made available on request.

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#### Appendix A. Supplementary data

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