Frequency of social media use and exposure to tobacco or nicotine-related content in association with E-cigarette use among youth: A cross-sectional and longitudinal survey analysis

Julia Vassey, Arthur Galimov, Chris J. Kennedy, Erin A. Vogel, Jennifer B. Unger

ARTICLE INFO

Keywords: Social media, Adolescents, Survey, E-cigarettes, Tobacco

ABSTRACT

Exposure to social media and its content featuring tobacco products is associated with e-cigarette use among adolescents. This study measured the association between frequency of Instagram, TikTok and YouTube use and exposure to tobacco-related content on each of these platforms with e-cigarette ever-use, current (past 30-day) use and initiation among adolescents. A cross-sectional and longitudinal analyses were used based on a self-reported survey conducted online in January – May 2021 – 2022 among socioeconomically- and racially-diverse Los Angeles, California high school students (N = 2036). Adolescents had higher odds of e-cigarette ever-use (adjusted odds ratio [AOR] = 2.16; CI: 1.20;3.90) and current (past 30-day) use (AOR = 3.11; CI: 1.64;5.89) if they used TikTok several times per day, compared to adolescents who used TikTok less frequently or not at all. Adolescents also had higher odds of e-cigarette initiation (AOR = 2.97; CI: 1.53;5.77) if they used TikTok daily or several times per day, compared to adolescents who used TikTok less frequently or not at all. Adolescents had higher odds of e-cigarette ever-use (AOR = 2.60; CI: 2.02;3.35) and current use (AOR = 3.11; CI: 1.64;5.89) if they reported seeing tobacco or nicotine posts, including e-cigarettes, on TikTok at least weekly. Frequent use of and frequent exposure to tobacco content on TikTok is associated with increased risk of e-cigarette use and initiation among adolescents. Tobacco-related content on social media popular among youth, especially on TikTok, requires stronger regulation and better enforcement by platforms of their policies restricting tobacco content.

1. Introduction

Electronic cigarettes (e-cigarettes) that include rechargeable and disposable pod devices (e.g., Puff Bar, Juul) are the most commonly used tobacco products among U.S. adolescents (Cooper, 2022). E-cigarette use is on the rise in 2022 (Park-Lee, 2021) with 2.55 million middle and high school students nationwide reporting past 30-day use of e-cigarettes (Cooper, 2022). E-cigarette use among adolescents can increase even further with schools reopening post-COVID, because adolescents typically obtain e-cigarettes from peers (Schiff, et al., 2021). Most e-cigarette products contain nicotine, which is highly addictive, can harm the developing adolescent brain, and can increase the risk for future addiction to other substances (Wang, 2020).

Online tobacco content is a risk factor for youth e-cigarette use (Donaldson et al., 2022). Posts about e-cigarettes are the most prevalent on social media compared to other tobacco-related posts (e.g., hashtag #vape on Instagram has over 30 million posts, which by far exceeds the number of posts related to cigars, cigarettes or other tobacco products on this platform). Exposure to social media and user-generated or promotional social media content related to e-cigarettes has been associated with use, initiation or intention to use e-cigarettes, as well as more positive attitudes towards and lower perceived harm of these products (Camenga et al., 2018; Kaleta et al., 2019; Lee, 2021; Vogel et al., 2021; Zheng et al., 2021). Among students in the 2021 National Youth Tobacco Survey (NYTS) who reported using social media, 73.5 % had seen e-cigarette–related content (Gentzke, 2022). Social media platforms,
including those that are popular among adolescents—e.g., Instagram, TikTok, YouTube, Snapchat (Rodriguez, 2021; Social networks used by teens in U.S. Statista, 2022) - restrict depiction and advertising of tobacco-related content (“Advertiser-friendly content guidelines: YouTube Help,” 2022; “Branded Content Policies,” 2020; “TikTok,” 2022). However, such bans are difficult to enforce, and user-generated and promotional e-cigarette-related posts are still present on these platforms (Laestadius et al., 2019; Rutherford et al., 2022). Promotional posts are often created by influencers (Vassey et al., 2022, 2021) - e.g., models, bloggers, or brand ambassadors who post about e-cigarettes on social media on behalf of tobacco brands and tend to glamorize e-cigarette products (Vassey et al., 2020). They portray e-cigarette use as a positive experience often in the context of humor and jokes, and a socially acceptable behavior (Sun et al., 2021). In addition, dedicated vaping forums and social media networking groups that discuss vaping and even form underground markets (McCauleland et al., 2021) contribute to creating the online environment that normalizes e-cigarette use. The Prototype Willingness Model (Gibbons and Gerrard, 1995) suggests that when people are considering joining a particular group (e.g., e-cigarette users) they often compare themselves with the prototype that they associate with that group (e.g., friends or glamourous influencers using e-cigarettes on social media). Based on this model, if adolescents observe friends, acquaintances, or influencers using e-cigarette products and appearing to be happy and popular on social media, they may see e-cigarette use as a behavior to emulate and perceive it as more normative and less risky (Vogels et al., 2021).

Prior research (Cavazos-Rehg et al., 2021; Donaldson et al., 2022) demonstrated an association between adolescent exposure to tobacco-related posts on social media (all social media platforms combined) and e-cigarette use, susceptibility or initiation. One study (Lee, 2021) showed an association between adolescent self-reported use of Instagram, Snapchat, Facebook and Twitter (as separate exposures) and e-cigarette use. Another study (Zheng et al., 2021) found that the association between social media use and e-cigarette use was mediated through online e-cigarette advertisement exposure and lower e-cigarette risk perception among U.S. youth, suggesting that it is the e-cigarette content, not general social media content, that is responsible for elevated e-cigarette use. It is important to note an increasing popularity year over year of video- and image-based platforms among U.S. adolescents (e.g., 95 % of them use YouTube, 67 % use TikTok and 62 % use Instagram) and declining interest in older, traditional, primarily text-based or multi-media platforms (e.g., 23 % of adolescents use Twitter and 32 % use Facebook), (Vogels et al., 2022). Considering this varying social media user experience and preferences, there is a need to separately examine and compare the association of the use of visual social media platforms popular among adolescents and tobacco-related content these platforms host with adolescent e-cigarette use.

In this study, we analyzed the use frequency of three social media platforms that were most popular among adolescents in 2022: Instagram, TikTok, and YouTube (Vogels et al., 2022) as well as the frequency of exposure to tobacco or nicotine-related content, including e-cigarettes, on each of these platforms in association with adolescent e-cigarette use and initiation. Our study also focused on Instagram, TikTok, and YouTube because these platforms have publicly accessible e-cigarette marketing content (Kong et al., 2022; Sun et al., 2021; Vassey et al., 2022), which the U.S. Federal Food and Drug Administration (FDA) has the authority (although limited) to regulate under the “deeming” rule (“Deeming Tobacco Products,” 2016). We assessed which of these three platforms might be risk factors for e-cigarette use initiation among youth, and, consequently, may need stronger enforcement of the platform’s own policy restricting tobacco-related content as well as additional scrutiny from tobacco control policy makers. While YouTube and Instagram were launched more than a decade ago, TikTok is still considered a relatively new, emerging platform (Vela, 2020). TikTok has been increasingly gaining popularity among adolescents competing with Instagram (Rodriguez, 2021) and overtaking YouTube based on average daily usage time by adolescents (MMGuardian, 2022). TikTok has engaging youth-appealing e-cigarette-related content often framed in the context of music and humor (Morales et al., 2022; Sun et al., 2021) in short video clips, which are often more popular among adolescents than longer YouTube videos (Jargon, 2022). We hypothesized that frequent use of TikTok, Instagram and YouTube and exposure to tobacco-related content on these platforms would be associated with adolescent e-cigarette use, but TikTok would have a stronger association with e-cigarette use than Instagram or YouTube.

2. Materials and methods

2.1. Procedure

In this study, we analyzed the Trends in Tobacco Use Survey (TITUS) conducted by the University of Southern California Tobacco Center of Regulatory Science (USC-TCORs). This longitudinal annual survey was designed to gather data on tobacco (including e-cigarettes) use behaviors, attitudes toward and perceptions of tobacco products and health risks from tobacco use among adolescents in 9th to 12th grades. Wave 1 (baseline) was conducted in 2019–2020 when the participants were in the 9th grade, Wave 2 was conducted in 2020–2021 and Wave 3 was conducted in 2021–2022. We analyzed Wave 2 and Wave 3 data for this study. (We did not analyze Wave 1 because the recruitment was affected by COVID and because TikTok was not included in the survey instrument at that wave).

2.2. Participants

School-based data were collected as part of a longitudinal survey of substance use and mental health among high school students. The schools were chosen based on their locations in the socioeconomically and racially diverse Los Angeles, California metropolitan area. Nine schools agreed to participate. Of the 2,262 eligible Wave 2 participants (who had parental consent and agreed to participate), 1,678 (74 %) completed Wave 2, and of the 2,478 eligible Wave 3 participants, 2,036 (83 %) completed Wave 3. A total of 1,463 (72 %) students completed both Wave 2 and Wave 3 surveys. All these participants reported whether they had used e-cigarettes or other tobacco, nicotine, marijuana products, or other substances (in their lifetime and in the past 30 days). Participants at Wave 2 were recruited and completed the 20-minute online survey, programmed in REDCap, on their personal devices remotely, on Zoom, due to school closures from the COVID-19 Pandemic. Trained research staff visited synchronous online classrooms, pulled out participating students into a separate Zoom meeting for survey taking, and monitored the process. At Wave 3 students completed the online survey in class on their classroom Chromebooks. Researchers obtained participants’ written informed assent and parental consent prior to data collection. The study was approved by the University of Southern California Institutional Review Board (UP-21-00352).

2.3. Measures

2.3.1. E-cigarette use

E-cigarette ever-use (lifetime), current (past 30-day) use and initiation (reported e-cigarette ever-use at Wave 3 by those who reported not using e-cigarettes at Wave 2) were the primary outcomes in this study. The researchers assessed e-cigarette ever-use with the following survey question in the e-cigarette-related section: “Have you ever used the following substances in your life?” with response options to four e-cigarette products: 1) e-cigarettes with nicotine (E-cigs, personal vaporizer), 2) JUUL, 3) disposable e-cigarette devices (Puff Bar, Mojo, Cali Bar, Hyppe Bar, Ezzy, etc.), 4) other e-cigarette products. E-cigarette use was coded as a binary variable (“yes” if one or more of these products was used, and “no” if none of these products were used). Current use was
assessed with the following survey question: “In the past 30 days, how many total days have you used…?” [with response options to four e-cigarette products listed above], (0 days, 1–2 days, 3–5 days, 6–9 days, 10–19 days, 20–29 days, all 30 days). E-cigarette use was coded as a binary variable (“yes” if one or more of these products was used for at least 1–2 days, and “no” if none of these products were used in the past 30 days). Analyzing the data using a more granular stratification of the current use: frequent use (20 days and above), (Cooper, 2022) vs less frequent use (below 20 days) vs never-use was not feasible in this study, because of the small sample size (n = 34) of the frequent past 30-day e-cigarette users.

2.3.2. Social media exposure

Frequency of Instagram, TikTok and YouTube use and frequency of exposure to (seeing) tobacco or nicotine content, including e-cigarettes, on these platforms were primary exposures in this study. Social media use frequency for cross-sectional analysis was assessed at Wave 3 and for longitudinal analysis was assessed at Wave 2 with the following survey question: “How often do you visit the following social media sites?” Separate questions were asked about each social media platform (i.e., Instagram, TikTok and YouTube). Response options were: “I do not use this form of social media”, “Monthly or less”, “Weekly”, “Daily”, “several times per day”, “Don’t know.” Based on the observed frequencies, responses were collapsed to a binary variable: “Daily or less frequently” (reference category) vs “several times per day” for exposure at Wave 3, and “Weekly or less frequently” (reference category) vs “Daily or several times per day” for exposure at Wave 2.

Frequency of exposure to nicotine or tobacco posts on Instagram, TikTok and YouTube was assessed at Wave 3 using the following survey question: “How often do you see a post about tobacco or nicotine (including e-cigarettes) on social media?” Separate questions were asked about each social media platform (i.e., Instagram, TikTok and YouTube). The response options were: “Monthly or less”, “Weekly”, “Daily”, “several times per day”, “Don’t know.” Based on the observed frequencies, responses were categorized as “Monthly or less frequently” (reference category) or “Weekly or more frequently.” For initiation the frequency of exposure to nicotine or tobacco posts was assessed at Wave 2 for Instagram and YouTube only, since the question about exposure to nicotine or tobacco posts on TikTok was added at Wave 3.

2.3.3. Covariates

Based on prior literature (Cavazos-Rehg et al., 2021; Kwon et al., 2018; Lee, 2021), we included the following predictors of e-cigarette use as covariates in our models: a) socio-demographic characteristics, i.e., age (15–17), sex at birth (male or female), race (White, Black, Asian, American Indian or Alaska Native (AIAN), Native Hawaiian or Pacific Islander (NHP)), Multi-race and Other), ethnicity (Latino or non-Latino), family financial status (well off, average, poor, it varies), parental education (above or below college level), language used at home (only or mostly English, English and another language, mostly or only another language); b) social norms related to e-cigarette use, i.e., e-cigarette use at home by family members or co-habitants (yes or no) and friends’ attitudes toward respondents’ e-cigarette use based on respondents’ assessment (“How would your best friends act towards you if you used e-cigarettes?” with response options being “very friendly/friendly” or “very unfriendly/unfriendly”); c) tobacco product use experience (one variable was created for ever-use of any of these products: combustible cigarettes, IQOS or other heated tobacco devices, dissolvable tobacco products (Snus), oral nicotine products (nicotine pouches, flavored nicotine gums, lozenges, gummies), big cigars, little cigars and cigarillos (LCCs), hookahs) and marijuana product use experience (one variable was created for ever-use of any of these products: smoking marijuana, vaping marijuana, blunts, edible marijuana products); d) harm perceptions of e-cigarettes (In your opinion, how harmful is using [a specified e-cigarette product listed above]?) assessed with the 5-point scale from “Not harmful at all” (1) to “Very harmful” (5)); and e) internalizing and externalizing disorders (Generalized Anxiety (Spitzer et al., 2006) and Social Anxiety Disorders (Chorpita et al., 2000)) measuring frequencies of episodes on the 4-point scale from “Not at all” (1) to “Nearly every day (4).” Harm perceptions of e-cigarettes and internalizing and externalizing disorders were continuous, while all the other variables were categorical or binary.

2.4. Statistical analysis

We calculated the prevalence of e-cigarette a) ever-use; b) non-current ever-use (excluding past 30-day use); c) current (past 30-day use and d) initiation, and measured bivariate associations of primary exposure variables and covariates with e-cigarette use status (ever-use vs never-use, non-current ever-use vs never-use and current use vs never-use) among the participants. Pearson’s chi-square tests were used for the categorical variables and T-tests were used for continuous variables to assess group differences between e-cigarette users and non-users.

We conducted 15 logistic regression models with fixed effects and clustered standard errors (“stglm function - BDocumentation,” 2022) to account for clustering by school (n = 9) to assess the association between frequency of Instagram, TikTok and YouTube use and frequency of exposure to tobacco or nicotine content on these platforms with e-cigarette ever-use, non-current ever-use, current use and initiation at Wave 3 (among never-users at Wave 2). Because of the intercorrelation of the predictors, seeing tobacco or nicotine posts were analyzed in separate models for each of the platforms, and social media use was also analyzed separately from seeing tobacco or nicotine posts (Table 1). All models were adjusted for the covariates described above. Results are presented separately for each platform. Because of the low respondent count for American Indian or Alaska Native (AIAN) and Native Hawaiian or Pacific Islander (NHP), these two race categories were added to the “Other” race category in the adjusted regression model.

A listwise deletion method was used to address missing data. There were no statistically significant demographic differences among the respondents who were removed from the analysis due to missing survey item-level data and those who were retained in the analysis (p > 0.05). Adjusted odds ratios (AORs) with 95 % confidence intervals (CIs) were reported with statistical significance set at p < 0.05 (two-tailed). Benjamini-Hochberg multiple testing corrections were applied to control the false discovery rate at 0.15. All statistical analyses were conducted using R software (version 4.0.2).

3. Results

3.1. Descriptive statistics and bivariate analysis at Wave 3

Among participants (N = 2,036) who completed the survey at Wave 3, 82 % were 16 years old, 55 % were female, 54 % were Latino, 52 %

| Table 1 | Overview of the adjusted logistic regression models used in the study. |
|---------|-----------------------------|
| Exposure | Instagram | YouTube | TikTok |
| E-cigarette ever-use (outcome) | | | |
| Social media use | | | |
| Seeing tobacco or nicotine posts | Model 2 | Model 3 | Model 4 |
| E-cigarette ever-use, excluding current use | | | |
| Social media use | | | |
| Seeing tobacco or nicotine posts | Model 6 | Model 7 | Model 8 |
| E-cigarette current use | | | |
| Social media use | | | |
| Seeing tobacco or nicotine posts | Model 10 | Model 11 | Model 12 |
| E-cigarette initiation at Wave 3 | | | |
| Social media use at Wave 2 | Model 14 | Model 15 | NA |
reported family income as “average”, 21 % reported non-current e-cigarette ever-use, and 8 % reported current (past 30-day) use. The majority of students used Instagram (59 %) and TikTok (53 %) several times per day and 46 % used YouTube several times per day (vs less frequent use). Over 20 % reported seeing tobacco or nicotine-related content, including e-cigarettes, on Instagram and TikTok at least weekly, and fewer respondents – 16 % reported seeing this content on YouTube. Bivariate associations of social media use, exposure to tobacco or nicotine-related content, and all covariates with e-cigarette use status (ever-use vs never-use, non-current ever-use vs never-use, and current use vs never use) are shown in Table 2. Frequency of social media use and exposure to nicotine/tobacco social media content as predictors of adolescent e-cigarette use (ever-user vs never-user, non-current ever-user vs never-user, and current user vs never-user) at Wave 3.

**Table 2**

Bivariate associations between frequency of social media use, frequency of exposure to/interaction with nicotine/tobacco social media content, and participant characteristics by e-cigarette use status (ever-user vs never-user, non-current ever-user vs never-user, and current user vs never-user) at Wave 3.

| E-cigarette use status at Wave 3 | Total (N = 2,036) (column %) | 429 (21 %) ever-users (including current users) | 269 (13 %) non-current ever-users (excluding current users) | 160 (8 %) current users (excluding non-current ever-users) | 1,607 (79 %) never-users |
|----------------------------------|-----------------------------|-----------------------------------------------|--------------------------------------------------------|--------------------------------------------------------|--------------------------|
| N (column % of ever-users)       | N (column % of never-users)  | N (column % of current users)                  | N (column % of never-users)                            | N (column % of never-users)                            |                          |
| Social Media Use                 |                             |                                               |                                                        |                                                        |                          |
| Instagram                        |                             |                                               |                                                        |                                                        |                          |
| No/don’t know                    | 207 (10 %)                  | 133 (31 %)***                                 | 83 (31 %)**                                            | 50 (31 %)*                                              | 659 (41 %)               |
| Weekly or less frequently        | 145 (7 %)                   |                                                |                                                        |                                                        |                          |
| Daily                            | 440 (22 %)                  |                                                |                                                        |                                                        |                          |
| Several times per day            | 1,195 (59 %)                | 281 (65 %)***                                 | 176 (65 %)**                                           | 105 (66 %)*                                             | 914 (57 %)               |
| NA (missing values)              | 49 (2 %)                    | 15 (4 %)                                      | 10 (4 %)                                               | 5 (3 %)                                                 | 34 (2 %)                 |
| YouTube                          |                             |                                               |                                                        |                                                        |                          |
| No/don’t know                    | 104 (5 %)                   |                                               |                                                        |                                                        |                          |
| Weekly or less frequently        | 449 (22 %)                  | 255 (59.5 %)***                              | 158 (59 %)*                                           | 97 (61 %)*                                              | 812 (50 %)               |
| Daily                            | 514 (25 %)                  |                                               |                                                        |                                                        |                          |
| Several times per day            | 927 (46 %)                  | 159 (37 %)***                                | 101 (37 %)*                                           | 58 (36 %)*                                              | 768 (48 %)               |
| NA (missing values)              | 42 (2 %)                    | 15 (3.5 %)                                    | 10 (4 %)                                               | 5 (3 %)                                                 | 27 (2 %)                 |
| TikTok                           |                             |                                               |                                                        |                                                        |                          |
| No/don’t know                    | 442 (22 %)                  |                                               |                                                        |                                                        |                          |
| Weekly or less frequently        | 154 (8 %)                   | 128 (30 %)***                                | 84 (31 %)***                                           | 44 (28 %)***                                            | 777 (48 %)               |
| Daily                            | 309 (15 %)                  |                                               |                                                        |                                                        |                          |
| Several times per day            | 1,089 (53 %)                | 287 (67 %)***                                | 175 (65 %)***                                          | 112 (70 %)***                                           | 802 (50 %)               |
| NA (missing values)              | 38 (2 %)                    | 14 (3 %)                                      | 10 (4 %)                                               | 4 (2 %)                                                 | 28 (2 %)                 |
| Seeing tobacco or nicotine posts |                             |                                               |                                                        |                                                        |                          |
| Instagram                        |                             |                                               |                                                        |                                                        |                          |
| No/don’t know                    | 558 (27 %)                  | 112 (26 %)                                    | 73 (27.1 %)                                            | 39 (24 %)                                               | 464 (28 %)               |
| Monthly or less frequently       | 723 (36 %)                  | 135 (32 %)*                                  | 84 (31.2 %)                                            | 51 (32 %)                                               | 588 (36 %)               |
| Weekly, daily or several times   | 484 (24 %)                  | 146 (34 %)***                                | 90 (33.5)***                                           | 56 (35 %)**                                             | 338 (21 %)               |
| per day                          | 271 (13 %)                  | 36 (8 %)                                      | 22 (8.2 %)                                             | 14 (9 %)                                                | 235 (15 %)               |
| YouTube                          |                             |                                               |                                                        |                                                        |                          |
| No/don’t know                    | 742 (37 %)                  | 151 (35 %)                                   | 97 (36 %)                                              | 54 (34 %)                                               | 591 (37 %)               |
| Monthly or less frequently       | 771 (38 %)                  | 151 (35 %)                                   | 90 (33 %)                                              | 61 (38 %)                                               | 620 (39 %)               |
| Weekly, daily or several times   | 335 (16 %)                  | 71 (17 %)                                    | 48 (18 %)                                              | 23 (14 %)                                               | 264 (16 %)               |
| per day                          | 188 (9 %)                   | 56 (13 %)                                    | 34 (13 %)                                              | 22 (14 %)                                               | 132 (8 %)                |
| TikTok                           |                             |                                               |                                                        |                                                        |                          |
| No/don’t know                    | 514 (25.2 %)                | 106 (25 %)                                   | 75 (28 %)                                              | 31 (19 %)*                                              | 408 (25.4 %)             |
| Monthly or less frequently       | 578 (28.4 %)                | 110 (26 %)***                                | 61 (22.5 %)***                                         | 58 (36 %)                                               | 468 (29.1 %)             |
| Weekly, daily or several times   | 448 (22 %)                  | 151 (35 %)***                                | 93 (34.5 %)***                                         | 49 (31 %)***                                            | 297 (18.5 %)             |
| per day                          | 496 (24.4 %)                | 62 (14 %)                                    | 40 (15 %)                                              | 22 (14 %)                                               | 434 (27 %)               |
| Socio-demographic covariates     |                             |                                               |                                                        |                                                        |                          |
| Age                              |                             |                                               |                                                        |                                                        |                          |
| 15 and other age                 | 96 (5 %)                    | 18 (4 %)                                      | 10 (3.7 %)                                             | 8 (5 %)                                                 | 80 (5 %)                 |
| 16                               | 1,649 (81 %)                | 350 (82 %)                                   | 225 (83.7 %)                                           | 125 (78 %)                                              | 1,299 (81 %)             |
| 17                               | 289 (14 %)                  | 61 (14 %)                                    | 34 (12.6 %)                                            | 27 (17 %)                                               | 228 (14 %)               |
| Gender                           |                             |                                               |                                                        |                                                        |                          |
| Male                             | 850 (42 %)                  | 149 (35 %)**                                 | 87 (32 %)**                                            | 62 (39 %)                                               | 701 (44 %)               |
| Female                           | 1,119 (55 %)                | 269 (63 %)**                                 | 174 (65 %)**                                           | 95 (59 %)                                               | 850 (53 %)               |
| NA (missing values)              | 67 (3 %)                    | 11 (2 %)                                      | 8 (3 %)                                                | 3 (2 %)                                                 | 56 (3 %)                 |
| Race                             |                             |                                               |                                                        |                                                        |                          |
| Asian                            | 448 (22 %)                  | 59 (14 %)***                                 | 37 (14 %)***                                           | 22 (14 %)**                                             | 389 (24 %)               |
| Black                            | 124 (6 %)                   | 26 (6 %)                                      | 15 (6 %)                                               | 11 (7 %)                                                 | 98 (6 %)                 |
| White                            | 576 (28 %)                  | 141 (33 %)*                                  | 73 (27 %)                                              | 68 (42 %)***                                            | 435 (27 %)               |
| Multi-race or Multi-ethnic       | 344 (17 %)                  | 93 (22 %)**                                  | 57 (21 %)*                                             | 36 (22 %)                                               | 251 (16 %)               |

(continued on next page)
Table 2 (continued)

| E-cigarette use status at Wave 3 | Total (N = 2,036) (column %) | 429 (21 %) ever-users (including current users) | 269 (13 %) non-current ever-users (excluding current users) | 160 (8 %) current users (excluding non-current ever-users) | 1,607 (79 %) never-users |
|----------------------------------|--------------------------------|---------------------------------|---------------------------------|---------------------------------|-------------------------|
| Total (N = 2,036) (column %) | 542 (27 %) | 104 (24 %) | 67 (25 %) | 37 (23 %) | 438 (27 %) |
| Other* (missing values) | 179 (9 %) | 36 (9 %) | 29 (11 %) | 9 (6 %) | 141 (9 %) |
| Ethnicity | | | | | |
| Latino | 1,097 (54 %) | 247 (58 %) | 166 (62 %)* | 81 (51 %) | 850 (53 %) |
| Non-Latino | 853 (42 %) | 165 (38 %) | 92 (34 %)* | 73 (45 %) | 688 (43 %) |
| NA (missing values) | 86 (4 %) | 17 (4 %) | 11 (4 %) | 6 (4 %) | 69 (4 %) |
| Family Financial Status | | | | | |
| Well off | 552 (27 %) | 116 (27 %) | 69 (26 %) | 47 (29 %) | 436 (27 %) |
| Average | 1,052 (52 %) | 212 (49.4 %) | 134 (50 %) | 78 (49 %) | 840 (52 %) |
| Poor | 102 (5 %) | 25 (6 %) | 17 (6 %) | 8 (5 %) | 77 (5 %) |
| It varied | 247 (12 %) | 62 (14.4 %) | 40 (15 %) | 22 (14 %) | 185 (12 %) |
| NA (missing values) | 83 (4 %) | 14 (3 %) | 9 (3 %) | 5 (3 %) | 69 (4 %) |
| Language used at home | | | | | |
| Mostly English | 1,138 (56 %) | 268 (62 %)* | 153 (57 %) | 115 (72 %)** | 870 (54 %) |
| English and another language | 604 (30 %) | 107 (25 %)* | 79 (29 %) | 28 (17 %)** | 497 (31 %) |
| Mostly another language | 224 (11 %) | 40 (9 %) | 29 (11 %) | 11 (7 %) | 184 (11.5 %) |
| NA | 70 (3 %) | 14 (3 %) | 8 (3 %) | 6 (4 %) | 56 (3.5 %) |
| Maternal education | | | | | |
| College or other advanced degrees | 1,172 (58 %) | 240 (56 %) | 141 (52 %) | 99 (62 %) | 932 (58 %) |
| Below college | 541 (26 %) | 138 (32 %)* | 97 (36 %)** | 41 (26 %) | 403 (25 %) |
| Don’t know | 251 (12 %) | 39 (9 %) | 23 (9 %) | 16 (10 %) | 212 (13 %) |
| NA (missing values) | 72 (4 %) | 14 (3 %) | 8 (3 %) | 5 (3 %) | 60 (4 %) |
| Paternal education | | | | | |
| College or other advanced degrees | 973 (48 %) | 207 (48 %) | 124 (46.1 %) | 83 (52 %) | 766 (48 %) |
| Below college | 641 (31 %) | 152 (35.5 %) | 98 (36.4 %) | 54 (34 %) | 489 (30 %) |
| Don’t know | 349 (17 %) | 58 (13.5 %) | 39 (14.5 %) | 19 (12 %) | 291 (18 %) |
| NA (missing values) | 73 (4 %) | 12 (3 %) | 8 (3 %) | 4 (2 %) | 61 (4 %) |
| Substance use history (ever-use) | | | | | |
| Other nicotine and tobacco products | | | | | |
| Yes | 195 (10 %) | 165 (38 %)** | 85 (32 %)** | 80 (50 %)** | 30 (2 %) |
| No | 1,841 (90 %) | 264 (62 %)** | 184 (68 %)** | 80 (50 %)** | 1,577 (98 %) |
| Marijuana | | | | | |
| Yes | 439 (22 %) | 331 (77 %)** | 201 (75 %)** | 130 (81 %)** | 108 (7 %) |
| No | 1,597 (78 %) | 98 (23 %)** | 68 (25 %)** | 30 (19 %)** | 1,499 (93 %) |
| Social environment related to e-cigarette use | | | | | |
| Use of e-cigarettes by family members or co-habitants | | | | | |
| Yes | 155 (8 %) | 69 (16 %)** | 35 (13 %)** | 34 (21 %)** | 86 (4 %) |
| No | 1,858 (91 %) | 352 (82 %)** | 228 (85 %)** | 124 (78 %)** | 1,506 (94 %) |
| NA (missing values) | 23 (1 %) | 8 (2 %) | 6 | 2 (1 %) | 15 (1 %) |
| Friends’ attitude toward survey participants’ e-cigarette use | | | | | |
| Friendly | 780 (38 %) | 294 (69 %)** | 162 (60 %)** | 132 (82.5 %)** | 486 (30 %) |
| Unfriendly | 1,256 (62 %) | 135 (31 %)** | 107 (40 %)** | 28 (17.5 %)** | 1,121 (70 %) |
| Survey participants’ harm perception of e-cigarettes | Mean/SD | 4.37/0.87 | 4.09*** | 4.23*** | 3.86*** | 4.44 |
| Internalizing and externalizing disorders | | | | | |
| Generalized Anxiety Disorder | 1.83/0.41 | 1.87* | 1.87’ | 1.87’ | 1.82 |
| Depression Scale (CES-D) | 1.05/0.31 | 1.09** | 1.09’ | 1.09’ | 1.04 |
| Social Anxiety Disorder | 0.62/0.29 | 0.66** | 0.65* | 0.67’ | 0.61 |

To assess bivariate associations Pearson’s chi-squared test was used for categorical variables and T-test was used for continuous variables. *** p-value < 0.001, ** p-value < 0.01, * p-value < 0.05, ‘ p-value < 0.1.

* E-cigarette ever-users, non-current ever-users and current users each were compared to never-users.

† Race categories are not mutually exclusive and sum up to above 100%.

‡ “Other” race category Includes American Indian or Alaska Native (AIAN) and Native Hawaiian or Pacific Islander (NHPi).

§ Other nicotine and tobacco products include combustible cigarettes, IQOS or other heated tobacco devices, dissolvable tobacco products (Snus), oral nicotine products (nicotine pouches, flavored nicotine gums, lozenges, gummies), big cigars, little cigars and cigarillos (LCCs), hookahs.

‖ Harm perception of e-cigarettes on the 5-point scale: 1 – not harmful at all to 5 – very harmful.

* Internalizing and externalizing disorders’ occurrences are measured on the 4-point scale: 1 – not at all to 4 – nearly every day.
Table 3: Frequency of social media use and exposure to nicotine/tobacco social media content as predictors of adolescent e-cigarette use (ever-user vs never-user, non-current ever-user vs never-user, and current user vs never-user) at Wave 3.

| Unadjusted Models | E-cigarette ever-use including current (past 30-day) use, unadjusted, OR (95 % CI) at Wave 3 |
|-------------------|------------------------------------------------------------------------------------------------------------------|
| Using social media | Instagram YouTube TikTok |
|                   |                       |
| several times per day (ref: once a day or less frequently) | 1.61*** (1.35;1.92) 0.69*** (0.57;0.84) 2.19*** (1.64;2.93) |
| Seeing tobacco or nicotine posts on social media | 1.84*** (1.27;2.67) 1.20 (0.92;1.57) 2.07*** (1.39;3.09) |
| Don’t know | 1.15 (0.80;1.63) 1.22* (1.03;1.45) 1.13 (0.67;1.89) |

| Adjusted Models | E-cigarette ever-use excluding current (past 30-day) use, unadjusted, OR (95 % CI) at Wave 3 |
|-----------------|------------------------------------------------------------------------------------------------------------------|
| Using social media | Instagram YouTube TikTok |
|                   |                       |
| several times per day (ref: once a day or less frequently) | 1.64*** (1.27;2.11) 0.70* (0.50;0.98) 2.07*** (1.56;2.75) |
| Seeing tobacco or nicotine posts on social media | 1.74*** (1.15;2.64) 1.34* (1.02;1.76) 2.24*** (1.49;3.37) |
| Don’t know | 1.11 (0.80;1.63) 1.28* (1.02;1.62) 1.34 (0.97;1.86) |

Significant ORs and AORs are reported based on the p-values that remained significant after applying Benjamini-Hochberg correction for multiple testing. For seeing tobacco or nicotine posts, the three platforms were analyzed in nine separate models because of high correlation (above 0.5) of the main exposure variables.

3.2. Multivariate analysis at Wave 3

Students had higher odds of e-cigarette ever-use (AOR = 2.06; CI: 1.32;3.20), non-current ever-use (AOR = 1.38; CI: 1.13;2.93) and current use (AOR = 3.11; CI: 1.64;5.89) if they used TikTok several times per day compared to students who used TikTok less frequently or not at all. Students had higher odds of e-cigarette ever-use (AOR = 2.27; CI: 1.69;3.04) and non-current ever-use (AOR = 2.66; CI: 2.02;3.35) if they reported seeing tobacco or nicotine posts, including e-cigarettes, on TikTok at least weekly, compared to students who reported seeing this content on TikTok monthly or less frequently (see Table 3). Students had higher odds of e-cigarette non-current ever-use (AOR = 1.57; CI: 1.03;2.40) if they reported seeing tobacco or nicotine posts, including e-cigarettes, on Instagram at least weekly, compared to students who reported seeing this content on Instagram monthly or less frequently. Students had higher odds of e-cigarette ever-use (AOR = 1.94; CI: 1.32;2.86) and non-current ever-use (AOR = 1.81; CI: 1.31;2.50), if they reported “I don’t know” in reference to seeing tobacco or nicotine posts, including e-cigarettes, on YouTube, compared to students who reported seeing this content on YouTube monthly or less frequently (see Table 3).

3.3. E-cigarette use initiation at 12-month follow-up.

Among the participants who had never used e-cigarettes at Wave 2 (N = 1,236), 9 % had initiated e-cigarette use in the next 12 months (at Wave 3). Bivariate associations of social media use, exposure to tobacco or nicotine-related content, and all covariates with e-cigarette use status (those who initiated e-cigarette use vs who did not initiate e-cigarette use) are shown in Table 4. In the multivariate analysis, only TikTok use was significantly associated with e-cigarette initiation. Students who used TikTok daily or several times per day had higher odds initiating e-cigarette use at Wave 3 (AOR = 2.97; CI: 1.53;5.77), compared to students who used TikTok less frequently or not at all (Table 5).

4. Discussion

This study demonstrated similarities and differences in the associations of e-cigarette ever-use, current use and initiation with use frequency of three social media platforms popular among youth (Instagram, YouTube and TikTok) and frequency of exposure to tobacco or nicotine-related content on these platforms among youth. Most students used the social media platforms several times per day, with a higher proportion of students – 59 % – using Instagram several times per day followed by TikTok (53 %) and YouTube (46 %). Over 20 % reported
Table 4
Bivariate associations between frequency of social media use and frequency of exposure to nicotine/tobacco social media content with participant characteristics by e-cigarette initiation status (initiators at Wave 3 vs non-initiators at Wave 3).

| Exposure at Wave 2 | Total (N = 1,236) (column %) | N (column % of e-cigarette users) | N (column % of e-cigarette non-users) |
|-------------------|-------------------------------|-----------------------------------|---------------------------------------|
| **Social Media Use** |                               |                                   |                                       |
| Instagram         |                               |                                   |                                       |
| Weekly or less frequently | 323 (26 %) | 15 (14 %)** | 308 (27 %)** |
| Daily or several times per day | 881 (71 %) | 92 (83 %)** | 795 (70 %)** |
| NA                | 32 (2 %) | 4 (3 %) | 28 (3 %) |
| YouTube           |                               |                                   |                                       |
| Weekly or less frequently | 233 (19 %) | 25 (22 %) | 208 (18.5 %) |
| Daily or several times per day | 975 (79 %) | 83 (75 %) | 892 (79.3 %) |
| NA                | 28 (2 %) | 3 (3 %) | 25 (2.2 %) |
| TikTok            |                               |                                   |                                       |
| Weekly or less frequently | 437 (15 %) | 20 (18 %)*** | 417 (37 %)*** |
| Daily or several times per day | 767 (53 %) | 88 (79 %)*** | 679 (60 %)*** |
| NA                | 32 (2 %) | 3 (3 %) | 29 (3 %) |
| **Seeing tobacco or nicotine posts** |                               |                                   |                                       |
| Instagram         |                               |                                   |                                       |
| Don’t know        | 338 (27 %) | 25 (22 %) | 318 (28 %) |
| Monthly or less frequently | 465 (38 %) | 41 (37 %) | 424 (38 %) |
| Weekly, daily or several times per day | 222 (18 %) | 34 (31 %)** | 181 (16 %)** |
| NA                | 211 (17 %) | 11 (10 %) | 200 (18 %) |
| YouTube           |                               |                                   |                                       |
| Don’t know        | 457 (37 %) | 39 (35 %) | 418 (37 %) |
| Monthly or less frequently | 454 (37 %) | 37 (33 %) | 417 (37 %) |
| Weekly, daily or several times per day | 214 (17 %) | 25 (23 %) | 189 (17 %) |
| NA                | 111 (9 %) | 10 (9 %) | 101 (9 %) |
| **Socio-demographic covariates** |                               |                                   |                                       |
| Age               |                               |                                   |                                       |
| 16 and other age  | 1,040 (84 %) | 97 (87 %) | 943 (84 %) |
| 17                | 196 (16 %) | 14 (13 %) | 182 (16 %) |
| Gender            |                               |                                   |                                       |
| Male              | 546 (42 %) | 48 (43 %) | 498 (44 %) |
| Female            | 684 (55 %) | 63 (57 %) | 621 (55 %) |
| NA                | 6 (3 %) | 0 | 6 (1 %) |
| **Race**          |                               |                                   |                                       |
| Asian             | 342 (28 %) | 20 (18 %)** | 322 (29 %)** |
| Black             | 81 (7 %) | 12 (11 %) | 69 (6 %) |
| White             | 314 (28 %) | 27 (24 %) | 287 (25 %) |
| Multi-race or Multi-ethnic | 223 (18 %) | 27 (24 %) | 196 (17 %) |
| Other             | 336 (17 %) | 27 (24 %) | 309 (27 %) |
| NA                | 65 (5 %) | 7 (6 %) | 58 (5 %) |
| **Ethnicity**     |                               |                                   |                                       |
| Latino            | 669 (54 %) | 69 (62 %) | 600 (53.4 %) |
| Non-Latino        | 550 (42 %) | 40 (36 %) | 510 (45.3 %) |
| NA                | 17 (4 %) | 2 (2 %) | 15 (1.3 %) |
| **Family Financial Status** |                               |                                   |                                       |
| Well off          | 344 (28 %) | 28 (25 %) | 316 (28 %) |
| Above average     | 688 (56 %) | 63 (57 %) | 625 (56 %) |
| Poor or it varied | 188 (15 %) | 19 (17 %) | 169 (15 %) |
| NA                | 16 (1 %) | 1 (1 %) | 15 (1 %) |
| **Language used at home** |                               |                                   |                                       |
| Mostly English    | 696 (56 %) | 67 (60 %) | 629 (56 %) |
| English and another language | 393 (32 %) | 32 (29 %) | 361 (32 %) |
| Mostly another language | 141 (11 %) | 11 (10 %) | 130 (11.5 %) |
| NA                | 6 (1 %) | 1 (1 %) | 5 (0.5 %) |
| **Maternal education** |                               |                                   |                                       |
| College or other advanced degrees | 730 (59 %) | 60 (54 %) | 670 (60 %) |
| Below college     | 319 (26 %) | 35 (32 %) | 284 (25 %) |
| Don’t know        | 180 (14.5 %) | 16 (14 %) | 164 (14.5 %) |
| NA                | 7 (0.5 %) | 0 | 7 (0.5 %) |
| **Paternal education** |                               |                                   |                                       |
| College or other advanced degrees | 620 (50 %) | 45 (40 %) | 575 (51 %) |
| Below college     | 373 (30 %) | 44 (40 %) | 329 (29 %) |

(continued on next page)
seeing tobacco or nicotine-related content, including e-cigarettes, on Instagram and TikTok at least weekly, and fewer respondents – 16% - reported seeing this content on YouTube. TikTok frequent use (several times per day compared to once a day or less frequently) was a significant predictor of ever-use, current use and initiation of e-cigarettes among adolescents in bivariate models and after controlling for covariates. Instagram appeared to be a risk factor associated with higher odds of e-cigarette ever-use and current use. For seeing tobacco or nicotine posts, the two platforms were analyzed in two separate models because of high correlation (above 0.5) of the main exposure variables.

### 4.1. Popularity of TikTok

There are a number of possible explanations of why TikTok use and exposure to nicotine or tobacco content on this platform was a strong significant predictor of e-cigarette ever- and current use among adolescents, while exposure to this content on Instagram was a weak predictor of e-cigarette ever-use (excluding current users) on Instagram.

To assess bivariate associations, Pearson’s chi-squared test was used for categorical variables and T-test was used for continuous variables. *** p-value < 0.001, ** p-value < 0.01, * p-value < 0.05, 'p-value < 0.1.

- Race categories are not mutually exclusive and sum up to above 100%.
- “Other” race category includes American Indian or Alaska Native (AIAN) and Native Hawaiian or Pacific Islander (NHP).
- Other nicotine and tobacco products include combustible cigarettes, IQOS or other heated tobacco devices, dissolvable tobacco products (Snus), oral nicotine products (nicotine pouches, flavored nicotine gums, lozenges, gummies), big cigars, little cigars and cigarillos (LCCs), hookahs.
- Harm perception of e-cigarettes on the 5-point scale: 1 – not harmful at all to 5 – very harmful.
- Internalizing and externalizing disorders’ occurrences are measured on the 4-point scale: 1 – not at all to 4 – nearly every day.
adolescents, but not Instagram or YouTube. TikTok is competing with Instagram in popularity among youth. Based on the Forrester Analytics Consumer Technographics US Youth Survey, in 2021, 63% of Gen Z youth - Americans between the ages of 12 and 17 - used TikTok on a weekly basis, compared with 57% for Instagram, while in 2020 61% of youth used Instagram compared to 50% for TikTok (Rodriguez, 2021). TikTok also overtook YouTube based on average daily usage time by adolescents (MMGuardian, 2022), which could be explained by the popularity of short, 15–30-second video clips (selfies), as opposed to longer YouTube videos which many teenagers might find harder to focus on (Jargon, 2022). In addition, TikTok content, including e-cigarette-related content, is often framed in the context of music and humor in these short video clips (Morales et al., 2022; Sun et al., 2021) and could be particularly appealing to youth – regardless of their e-cigarette, marijuana or other tobacco product use status (which were among the covariates we controlled for in this study).

4.2. Organic vs promotional content on TikTok and Instagram

TikTok is still predominantly a user-generated platform while Instagram has a higher prevalence of promotional content. For example, in 2020, 96% of different brands used influencers on Instagram as a promotional tool in their campaigns, while only 7% of brands used influencers on TikTok (Instagram vs. TikTok: What the Future Holds for Social Media Marketing, 2021; “TikTok and Instagram,” 2022). Studies (Vogel et al., 2020) showed that sponsored content is often perceived by social media users as less authentic and consequently less engaging compared to organic user-generated content. Since influencers mention e-cigarette brands (e.g., @brandname) they partner with on Instagram (Vassey et al., 2022), - although often without direct indication that this content is sponsored (e.g., “paid partnership”) - youth may perceive Instagram content as less authentic, and it may be consequently less influential on youth e-cigarette use behavior. But if youth perceive e-cigarette content on TikTok as more authentic compared to Instagram (because TikTok e-cigarette content is rarely labeled as promotional based on our observations), it may have a stronger effect on youth e-cigarette use behavior. A study quantitatively assessing and comparing the prevalence of e-cigarette content labeled as promotional on Instagram vs TikTok could be an important direction for future research to test this hypothesis.

4.3. Content recommendation algorithm on TikTok and Instagram

Finally, both Instagram and TikTok have recommendation algorithms which determine which images or videos appear on a user’s page (based on the user’s interaction with the platforms’ content). But unlike Instagram (The 2022 Instagram Algorithm Explained, 2022), a highly personalized TikTok’s “For You” algorithm does not base recommendations on follower count or on a history of previous high-performing videos in users’ feed (“How the TikTok Algorithm Works in 2022 (and How to Work With It),” 2022). This could potentially indicate a higher probability for a user to stumble upon new content categories and discover new content creators (e.g., including e-cigarette brand ambassadors) on TikTok than on Instagram. Although recently TikTok announced that content showing the use of tobacco products would not be eligible for recommendation (“What is the For You feed?,” 2020), the effectiveness of this policy is unknown. While content distribution was beyond the scope of this study, it could be an important direction for future research.

4.4. Anti-e-cigarette content on YouTube

Although the association between frequent use of YouTube and lower odds of e-cigarette use among adolescents was not significant in the multivariate model, the association was significant in the bivariate model. While YouTube has pro-e-cigarette videos documented in research (Kong et al., 2022, 2019), fewer respondents – 16% - reported seeing this content on YouTube (compared to over 20% for either Instagram or TikTok). YouTube could also potentially have higher prevalence of anti-e-cigarette videos on this platform, compared to TikTok and Instagram. The Truth Initiative partnered with TikTok influencers and current e-cigarette users to produce a video series on YouTube to encourage youth to quit vaping (“truth orange - YouTube,” 2022). Based on the 2021 NYTS survey data (Gentzke, 2022), 75% of middle and high school students reported having seen or heard any anti-tobacco public education campaign ad within the past year. An estimated 15.8 million (61%) students reported recognizing the FDA’s “The Real Cost” campaign ad about risks of e-cigarette use for adolescents (FDA, 2018). Future research should quantitatively assess and compare the prevalence of anti-e-cigarette content on YouTube compared to Instagram and TikTok. Future studies on other adolescent populations should also examine if YouTube use is indeed a protective factor for e-cigarette use among youth. Finally, estimating the effect of exposure to e-cigarette counter-marketing on YouTube using survey experiments on adolescent e-cigarette use could be another important direction for future research.

4.5. Limitations

The sample in this research was limited to students studying in nine high schools located in southern California, which might limit generalizability to other geographic areas. To enhance generalizability, future research should include students from the schools across different regions in the U.S. Because of social-desirability and recall bias, some e-cigarette use could have been underreported. Because of the relatively low prevalence of current e-cigarette use and initiation in this sample, future research should confirm the robustness of these findings. We did not analyze students’ awareness of e-cigarette-related content by account type (i.e., posted by peers, celebrities or influencers), but we will explore these research directions in future studies.

5. Conclusions

TikTok, which is inundated with e-cigarette user-generated and promotional posts, potentially expose youth to harmful content that is associated with adolescent e-cigarette use. E-cigarette-related posts on social media, and especially on TikTok, require stronger regulation, including better enforcement by social media platforms of their existing policies that prohibit showing and promoting e-cigarette content. Improved enforcement may require automated methods such as deep learning-based tracking of e-cigarette promotion (Kennedy et al., 2021). Federal agencies could also require better compliance with the Federal Trade Commission (FTC) requirements (“FTC Releases Advertising Disclosures Guidance for Online Influencers,” 2019) for sponsorship disclosures in promotional posts. At the same time, more anti-e-cigarette youth-appealing content, including educational or advocacy campaigns featuring influencers or even members of general public, should be disseminated on social media platforms popular among youth.

CRediT authorship contribution statement

Julia Vassey: Conceptualization, Formal analysis, Methodology, Software, Writing – original draft, Writing – review & editing. Arthur Galimov: Methodology, Writing – review & editing, Chris J. Kennedy: Methodology, Writing – review & editing. Erin A. Vogel: Writing – review & editing. Jennifer B. Unger: Data curation, Funding acquisition, Methodology, Supervision, Writing – review & editing.

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.

Acknowledgements
The authors acknowledge the contribution of Project Director Daniel Soto and Data Management Coordinator Lauren Howard, Institute of Health Promotion and Disease Prevention Research, University of Southern California, for assisting in survey data curation.

Funding
Research reported in this publication was supported by the National Institute of Health (Grant # 1R01CA260459-01), the California Tobacco-Related Disease Research Program Award (TRDRP Grant # 26IR-0016) and the National Cancer Institute and the FDA Center for Tobacco Products (CTP) Award (NCI/FDA Grant #U54CA180905). The funders had no role in study design; collection, analysis, and interpretation of data; writing the report; and the decision to submit the report for publication. The content is solely the responsibility of the authors and does not necessarily represent the official views of the funders.

Data Availability Statement
Data supporting the conclusions of this manuscript will be made available by the authors, without undue reservation and in compliance with the IRB protocol, to any qualified researcher.

References
Advertiser-friendly content guidelines - YouTube Help, 2022. URL: https://support.google.com/youtube/answer/6162278?hl=en (accessed 4.4.21).
Branded Content Policies. Facebook Business Help Center. 2020. URL: https://www.facebook.com/business/help/221149189008254 (accessed 5.20.20).
Camenga, D., Gutierrez, K., Kong, G., Cavallio, D., Simon, P., Krishnan-Sarin, S., 2018. E-cigarette advertising exposure in e-cigarette naive adolescents and subsequent e-cigarette use: a longitudinal cohort study. Addict. Behav. 81 https://doi.org/10.1016/j.addbeh.2018.02.008.
Cavazos-Rehg, P., Li, X., Kasson, E., Kaiser, N., Borodovsky, J.T., Grucza, R., Chen, L.-S., 2019. Promotion of vape tricks on youtube: content analysis. J. Med. Internet Res. 21, e2709.
Kwon, E., Seo, D.-C., Lin, H.-C., Chen, Z., 2018. Predictors of youth e-cigarette use susceptibility in a U.S. nationally representative sample. Addict. Behav. 79, 79-85. https://doi.org/10.1016/j.addbeh.2018.02.026.
Laestadius, L.L., Wahl, M.M., Pokrèl, P., Cho, Y.L., 2019. From Apple to Werewolf: A study of young adults in Southern California. Nicotine Tobacco Res. 23 https://doi.org/10.1097/01.pol.0000570966.24669.72.
McGeary, R., Mayock, B., Leaver, T., Wolf, K., Freeman, B., Jancey, J., 2021. ‘Is it banned? Is it illegal?’: Navigating Australia’s regulatory environment for e-cigarettes. International Journal of Drug Policy 94, 103177. https://doi.org/10.1016/j.drugpo.2021.103177.
MMGuardians. TikTok 2022: A New Tool Is Now the Most Used App by Teens & Pre-teens in the US. URL: https://www.mmguardians.com/news-releases/tiktok-is-now-the-most-used-app-by-teens-pre-teens-in-the-us-30125369.9.html (accessed 6.6.22).
Moralès, M., Fabrion, A., Watkins, S.L., 2022. #NicotineAddictionCheck: puff bar culture, addiction apathy, and promotion of e-cigarettes on TikTok. Int. J. Environ. Res. Public Health 19, 3901. https://doi.org/10.3390/ijerph190303901.
Park-Lee, E., 2021. Notes from the Field: E-Cigarette Use Among Middle and High School Students — National Youth Tobacco Survey, United States, 2021. MMWR Morb Mortal Wkly Rep. 70. https://doi.org/10.15585/mmwr.mm7039a3.
Jargon, J., 2022. TikTok Brain Explained: Why Some Kids Seen Hooked on Social Video Feeds. WSJ. URL: https://www.wsj.com/articles/tiktok-brain-explained-why-some-kids-seem-hooked-on-social-video-feeds-1146886692 (accessed 6.6.22).
Kaleta, D., Niedzink, M., Jankowska, A., Polanska, K., 2019. Predictors of E-cigarette use susceptibility—a study of young people from a socio-economically disadvantaged rural area in Poland. Int. J. Environ. Res. Public Health 16, 3935. https://doi.org/10.3390/ijerph16020395.
Kennedy, C.J., Vassey, J., Chang, H.-C.H., Unger, J.B., Ferrara, E., 2021. Tracking e-cigarette warning label compliance on YouTube through machine learning. Tob Control 2021-057243. https://doi.org/10.1136/tobaccocontrol-2021-057243.
Kong, G., Schott, A.S., Lee, J., Dastan, H., Murthy, D., 2022. Understanding e-cigarette content and promotion on YouTube through machine learning. Tob Control 2021-057243. https://doi.org/10.1136/tobaccocontrol-2021-057243.
Jorgenson, J., Sun, T., Lim, C.C.W., Chung, J., Cheng, B., Davidson, L., Tisdale, C., Leung, J., Gartner, C., 2022. Social networks used by teens in U.S. Statista. URL: https://www.statista.com/statistics/469268/social-networks-popularity-among-teens/ (accessed 6.1.22).
Gramja, J., 2022. TikTok vs. TikTok: What the Future Holds for Social Media Marketing — Footwear News. URL: https://footwearnews.com/2021/business/marketing/instagram-vs-tiktok-social-media-marketing/1203126936/ (accessed 5.22.22).
Pack-Lee, E., 2021. Notes from the Field: E-Cigarette Use Among Middle and High School Students — National Youth Tobacco Survey, United States, 2021. MMWR Morb Mortal Wkly Rep. 70. https://doi.org/10.15585/mmwr.mm7039a4.
FTC Releases Advertising Disclosures Guidance for Online Influencers. Federal Trade Commission, 2019. URL: https://www.ftc.gov/news-events/press-releases/2019/11/ftc-releases-advertising-disclosures-guidance-online-influencers (accessed 5.22.22).
Rothfuss, B.F., Yin, L., Moffitt, C., Umemoto, L.A., Francis, S.E., 2000. Assessment of symptoms of DSM-IV anxiety and depression in children: a revised child anxiety and depression scale. Behav. Res. Ther. 38, 835-855. https://doi.org/10.1016/S0005-7967(99)00130-6.
Corwin, M.W., 2022. Notes from the Field: E-cigarette Use Among Middle and High School Students — United States, 2022. MMWR Morb. Mortal Wkly. Rep. 71. https://doi.org/10.15585/mmwr.mm7140a3.
Donaldson, S.I., Dormaneh, A., Perez, C., Majmundar, A., Allen, J.P., 2022. Association between exposure to tobacco content on social media and tobacco use: a systematic review and meta-analysis. JAMA Pediatr. 176, 878-885. https://doi.org/10.1001/jamapediatrics.2022.2223.
DFA launches new, comprehensive campaign to warn kids about the dangers of e-cigarette use as part of agency’s Youth Tobacco Prevention Plan, amid evidence of sharply rising use among kids, 2018. URL: http://www.dfa.gov/news-events/press-announcements/dfa-launches-new-comprehensive-campaign-warn-kids-about-dangers-e-cigarette-use-part-agencys-youth (accessed 1.12.20).
fteglm function - RDocumentation, 2022. URL: https://www.rdocumentation.org/packages/fixest/topics/feglm (accessed 5.25.22).
Gentzke, A.S., 2022. Tobacco Product Use and Associated Factors Among Middle and High School Students — National Youth Tobacco Survey, United States, 2021. MMWR Surveill Summ 71. https://doi.org/10.15585/mmwr.su7105a1.
Gibbons, F.X., Garrard, M., 1995. Predicting young adults’ health risk behavior. J. Pers. Soc. Psychol. 69, 505-517. https://doi.org/10.1037/0022-3514.69.3.505.
The TikTok Algorithm Works in 2022 (and How to Work With It). Social Media Marketing & Management Dashboard. URL: https://blog.hostsuite.com/tiktok-algorithm/ (accessed 5.27.22).
Instagram vs. TikTok: What the Future Holds for Social Media Marketing – Footwear News. 2021. URL: https://footwearnews.com/2021/business/marketing/instagram-vs-tiktok-social-media-marketing/1203126936/ (accessed 5.22.22).

Preventive Medicine Reports 30 (2022) 102055

Vassey, J., Metayer, C., Kennedy, C.J., Whitehead, T.P., 2020. #Vape: measuring E-cigarette influence on Instagram with deep learning and text analysis. Front. Commun. 4 https://doi.org/10.3389/fcomm.2019.00075.

Vassey, J., Allem, J.-P., Barker, J., Cruz, T.B., Pang, R., Unger, J.B., Wipfli, H.L., Kirkpatrick, M., 2021. E-cigarette use and promotion by social media influencers during videogame play on Twitch. Tobacco Control. https://doi.org/10.1136/tobaccocontrol-2021-056626.

Vassey, J., Valente, T., Barker, J., Stanton, C., Li, D., Laestadius, L., Cruz, T.B., Unger, J.B., 2022. E-cigarette brands and social media influencers on Instagram: a social network analysis. Tobacco Control. https://doi.org/10.1136/tobaccocontrol-2021-057053.

Vela, G., 2020. Council post: TikTok: the next frontier of social media is here. Forbes. URL: https://www.forbes.com/sites/forbesagencycouncil/2020/03/19/tiktok-the-next-frontier-of-social-media-is-here/ (accessed 6.14.22).

Vogel, E.A., Guillory, J., Ling, P.M., 2020. Sponsorship disclosures and perceptions of E-cigarette Instagram posts. Tobacco Regul. Sci. 6, 355–368. https://doi.org/10.18001/TRS.6.5.5.

Wang, T.W., 2020. E-cigarette use among middle and high school students — United States, 2020. MMWR Morb Mortal Wkly Rep 69. https://doi.org/10.15585/mmwr.mm6937e1.

Zheng, X., Li, W., Wong, S.-W., Lin, H.-C., 2021. Social media and E-cigarette use among US youth: Longitudinal evidence on the role of online advertisement exposure and risk perception. Addict. Behav. 119, 106916 https://doi.org/10.1016/j.addbeh.2021.106916.