

Online Tobacco Marketing and Subsequent Tobacco Use

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abstract

BACKGROUND: Nearly 2.9 million US adolescents engaged with online tobacco marketing in 2013 to 2014. We assess whether engagement is a risk factor for tobacco use initiation, increased frequency of use, progression to poly-product use, and cessation.

METHODS: We analyzed data from 11 996 adolescents sampled in the nationally representative, longitudinal Population Assessment for Tobacco and Health study. At baseline (2013–2014), we ascertained respondents' engagement with online tobacco marketing. At follow-up (2014–2015), we determined if respondents had initiated tobacco use, increased frequency of use, progressed to poly-product use, or quit. Accounting for known risk factors, we fit a multivariable logistic regression model among never-users who engaged at baseline to predict initiation at follow-up. We fit similar models to predict increased frequency of use, progression to poly-product use, and cessation.

RESULTS: Compared with adolescents who did not engage, those who engaged reported higher incidences of initiation (19.5% vs 11.9%), increased frequency of use (10.3% vs 4.4%), and progression to poly-product use (5.8% vs 2.4%), and lower incidence of cessation at follow-up (16.1% vs 21.5%). Accounting for other risk factors, engagement was positively associated with initiation (adjusted odds ratio [aOR] = 1.26; 95% confidence interval [CI]: 1.01–1.57), increased frequency of use (aOR = 1.58; 95% CI: 1.24–2.00), progression to poly-product use (aOR = 1.70; 95% CI: 1.20–2.43), and negatively associated with cessation (aOR = 0.71; 95% CI: 0.50–1.00).

CONCLUSIONS: Engagement with online tobacco marketing represents a risk factor for adolescent tobacco use. FDA marketing regulation and cooperation of social-networking sites could limit engagement.



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WHAT'S KNOWN ON THIS SUBJECT: Nearly 12% of US adolescents (2.9 million) engaged with online tobacco marketing in 2013–2014; these adolescents may be more susceptible to tobacco use initiation because online tobacco marketing may alter perceived norms and alter risk perceptions associated with tobacco use.

WHAT THIS STUDY ADDS: Adolescents' engagement with online tobacco marketing was associated with higher incidence of tobacco use initiation, increased frequency of tobacco use, and progression to poly-product use, and lower incidence of tobacco use cessation. Marketing regulation by the Food and Drug Administration could limit engagement.

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The tobacco industry has shifted marketing efforts away from traditional forms of marketing to the Internet since the 1998 Master Settlement Agreement.¹ Expenditure on Internet-based tobacco marketing has increased nearly 25-fold: \$0.9 million in 1999 to \$23.3 million in 2014 (both in 2014 US dollars), whereas expenditure on print magazine advertising has decreased nearly ninefold: \$563.5 million in 1999 to \$68.9 million in 2014 (both in 2014 US dollars).^{2,3} Internet-based marketing affords several advantages. First, whereas traditional marketing (eg, print advertisements) are addressed by the Master Settlement Agreement, online marketing is largely unregulated. Second, Internet marketing enables tobacco companies to target individuals through direct-to-consumer advertising, which encourages consumers to engage in promoted activities.⁴ Additionally, Internet marketing facilitates and encourages interaction among individuals.^{1,5–8} Youth may be especially vulnerable to online marketing because of high levels of Internet and social media use and sensitivity to tobacco advertising.^{9–12} The authors of a 2006 meta-analysis of 51 studies concluded that highly engaging traditional tobacco marketing (ie, that which elicits marketing receptivity) was even more effective at promoting tobacco use among adolescents than less engaging marketing.¹⁰ Nearly 12% of US adolescents (2.9 million) engaged with online tobacco marketing in 2013 to 2014; online marketing may make these adolescents more susceptible to tobacco use initiation by altering perceived norms and risk perceptions regarding tobacco use.^{13,14}

Although we know engagement with online tobacco marketing (engagement) is cross-sectionally associated with susceptibility to tobacco use initiation among

adolescents, we do not yet know if engagement among those who have never used tobacco (never-users) increases their risk of tobacco use initiation. We also do not know how engagement affects tobacco use progression and cessation among tobacco-using adolescents. Previous advertising and promotional efforts, such as print media advertisements, by the tobacco industry led to tobacco use initiation and progression among youth.¹⁵ Online tobacco marketing engagement may represent a new public health threat if it also alters tobacco use behaviors.¹⁵ Engagement may be even more problematic than previous promotional efforts because it provides greater exposure to protobacco content and enhances advertisement effectiveness.^{4,5,13}

In this study, we address this research gap by assessing the longitudinal association between online tobacco marketing engagement and subsequent tobacco use initiation, increased frequency of product use (increased frequency), progression to poly-tobacco product use (poly-product use), and cessation of tobacco product use (cessation). We hypothesize that after accounting for exposure to offline tobacco marketing as well as known demographic, psychosocial, and behavioral risk factors, engagement will increase the risk of initiation and progression and decrease the likelihood of cessation.

METHODS

Data

We used data from the first 2 waves of the Population Assessment for Tobacco and Health (PATH) study, a nationally representative longitudinal cohort study conducted by the National Institute on Drug Abuse and the Food and Drug Administration's (FDA's) Center for Tobacco Products. At baseline (2013–2014), the PATH study

sampled 13 651 adolescents, and 1655 were lost to follow-up (2014–2015). Further details regarding the PATH study were published by Hyland et al.¹⁶ The Dartmouth College Committee for the Protection of Human Subjects determined that the regulatory definition of human subjects research (45 CFR 46.102[f]) did not apply to this study and that institutional review board review was unnecessary.

We observed differential attrition between Waves 1 and 2; adolescents who were older, had a high weekly income, and used a smartphone were more likely to be lost to follow-up (Table 1). Respondents lost and not lost to follow-up were similarly likely to have engaged with online tobacco marketing (11.0% vs 12.0%, $P = .24$). Compared with respondents retained for analysis, those lost to follow-up were more likely to have been ever-users at baseline (24.7% vs 21.4%, $P = .005$) and to have used in the past year (18.3% vs 15.7%, $P = .01$).

Outcomes

We examined 4 outcomes at follow-up: (1) initiation of tobacco use, (2) increased frequency of tobacco product use in the past 30 days, (3) progression from single-product to poly-product use (ie, ≥ 2 products), and (4) cessation of tobacco product use. We considered the following tobacco products: cigarettes, electronic cigarettes (e-cigarettes), cigars (traditional, cigarillos, and little filtered cigars), hookah, pipe, snus pouches and other smokeless tobacco, dissolvable tobacco, bidi, and kretek. First, we considered a respondent to have initiated tobacco use if she or he reported to have never used any tobacco product at baseline and then reported at follow-up to have used at least 1 tobacco product in the past 12 months. Second, we defined total consumption of a given tobacco product in the past 30 days (total consumption) as the number of

TABLE 1 Sample Characteristics Among All Baseline Respondents, Baseline Respondents With Follow-up, and Baseline Respondents Without Follow-up

Variable	N	All Baseline Respondents (N = 13 651)	Baseline Respondents With Follow-up (N = 11 996)	Baseline Respondents Without Follow-up (N = 1655)	P
		Prevalence, % (95% CI)	Prevalence, % (95% CI)	Prevalence, % (95% CI)	
Age group, y					
12–14	6997	50.4 (49.6–51.3)	51.0 (50.0–51.9)	46.7 (44.2–49.3)	.001
15–17	6653	49.6 (48.7–50.4)	49.0 (48.1–50.0)	53.3 (50.7–55.8)	.001
Sex					
Female	6657	48.7 (47.8–49.6)	48.7 (47.8–49.7)	48.4 (45.8–51.0)	.80
Male	6993	51.3 (50.4–52.2)	51.3 (50.3–52.2)	51.6 (49.0–54.2)	.80
Race and/or ethnicity					
Non-Hispanic white	6614	54.5 (53.7–55.4)	54.6 (53.7–55.5)	54.2 (51.7–56.8)	.78
Hispanic	3920	22.3 (21.6–22.9)	22.4 (21.7–23.1)	21.4 (19.5–23.2)	.33
Non-Hispanic African American	1859	13.9 (13.3–14.5)	13.9 (13.2–14.5)	14.0 (12.2–15.8)	.86
Non-Hispanic other	1257	9.3 (8.7–9.8)	9.1 (8.6–9.7)	10.4 (8.6–12.1)	.12
Parental education					
At least some college	8147	63.9 (63.0–64.7)	64.4 (63.5–65.3)	60.4 (57.9–62.9)	.002
High school graduate	2570	18.1 (17.4–18.8)	17.8 (17.0–18.5)	20.5 (18.5–22.6)	.009
Less than high school	2834	18.0 (17.4–18.7)	17.9 (17.2–18.6)	19.1 (17.1–21.0)	.26
Weekly income					
None or <\$1	4931	37.0 (36.1–37.8)	37.2 (36.3–38.1)	35.3 (32.9–37.8)	.14
\$1–\$20	5696	41.6 (40.7–42.5)	42.0 (41.1–42.9)	39.1 (36.6–41.7)	.03
\$21–\$50	1406	10.5 (9.9–11.0)	10.3 (9.7–10.9)	11.8 (10.1–13.4)	.08
\$51+	1429	10.9 (10.4–11.5)	10.5 (9.9–11.1)	13.8 (12.0–15.5)	<.001
School performance					
Mostly As	3359	26.5 (25.7–27.3)	27.1 (26.2–27.9)	22.6 (20.4–24.8)	<.001
As and Bs	4641	33.8 (33.0–34.7)	33.8 (32.9–34.7)	34.3 (31.8–36.7)	.69
Mostly Bs	1186	8.8 (8.3–9.3)	8.7 (8.2–9.3)	9.0 (7.5–10.5)	.71
Bs and Cs	2596	18.3 (17.6–19.0)	18.1 (17.3–18.8)	19.8 (17.8–21.9)	.09
Mostly Cs to mostly Fs	1721	12.0 (11.4–12.5)	11.8 (11.2–12.4)	13.4 (11.7–15.1)	.07
School ungraded	80	0.6 (0.5–0.8)	0.6 (0.4–0.7)	1.0 (0.4–1.5)	.14
Internet access					
Several times a day	8324	62.2 (61.3–63.0)	62.2 (61.3–63.2)	61.7 (59.2–64.2)	.68
Approximately once a d	2005	15.0 (14.3–15.6)	15.1 (14.4–15.8)	14.0 (12.2–15.8)	.23
3–5 d a wk	1308	9.3 (8.8–9.8)	9.4 (8.8–9.9)	8.9 (7.5–10.3)	.53
1–2 d a wk	551	3.9 (3.6–4.3)	3.9 (3.5–4.2)	4.2 (3.2–5.2)	.58
Less than once a wk	1415	9.6 (9.1–10.1)	9.4 (8.9–9.9)	11.2 (9.6–12.8)	.03
Social networking account use					
Several times a day	4452	34.6 (33.8–35.5)	34.4 (33.5–35.3)	36.3 (33.7–38.8)	.15
Daily	3725	28.6 (27.7–29.4)	28.8 (27.9–29.7)	26.9 (24.6–29.3)	.12
Weekly	1593	12.2 (11.6–12.8)	12.4 (11.7–13.0)	11.1 (9.4–12.8)	.13
Monthly or less	3193	24.6 (23.8–25.4)	24.4 (23.6–25.3)	25.7 (23.4–28.1)	.27
Use smartphone					
No	4144	30.2 (29.3–31.0)	30.7 (29.8–31.5)	26.6 (24.3–28.9)	<.001
Yes	9470	69.8 (69.0–70.7)	69.3 (68.5–70.2)	73.4 (71.1–75.7)	<.001
Sensation seeking					
Low	4563	33.3 (32.5–34.2)	33.2 (32.3–34.1)	34.5 (32.1–37.0)	.28
Moderate	5228	38.4 (37.5–39.3)	38.3 (37.4–39.2)	39.1 (36.6–41.6)	.54
High	3844	28.2 (27.4–29.0)	28.5 (27.6–29.4)	26.4 (24.1–28.6)	.07
Internalizing problems					
Low	5068	37.1 (36.3–38.0)	36.6 (35.7–37.6)	40.5 (37.9–43.0)	.003
Moderate	4092	29.9 (29.1–30.8)	30.0 (29.1–30.8)	29.8 (27.4–32.1)	.87
High	4491	32.9 (32.1–33.8)	33.4 (32.5–34.3)	29.8 (27.4–32.1)	.003
Externalizing problems					
Low	3672	26.5 (25.7–27.3)	25.9 (25.1–26.7)	30.6 (28.3–33.0)	<.001
Moderate	3731	27.4 (26.6–28.2)	27.2 (26.3–28.0)	28.9 (26.5–31.2)	.16
High	6248	46.1 (45.2–47.0)	46.9 (46.0–47.9)	40.5 (38.0–43.0)	<.001
Currently lives with a tobacco user					
No	8709	65.4 (64.6–66.3)	65.7 (64.8–66.6)	63.5 (61.0–66.0)	.08
Yes	4827	34.6 (33.7–35.4)	34.3 (33.4–35.2)	36.5 (34.0–39.0)	.08
Exposure to tobacco coupons by mail					
No	13 079	95.9 (95.6–96.3)	95.8 (95.4–96.1)	97.1 (96.2–97.9)	.004
Yes	572	4.1 (3.7–4.4)	4.2 (3.9–4.6)	2.9 (2.1–3.8)	.004

TABLE 1 Continued

Variable	N	All Baseline Respondents	Baseline Respondents With	Baseline Respondents Without	P
		(N = 13 651)	Follow-up (N = 11 996)	Follow-up (N = 1655)	
		Prevalence, % (95% CI)	Prevalence, % (95% CI)	Prevalence, % (95% CI)	
Exposure to other tobacco information by mail					
No	13 488	98.8 (98.7–99.0)	98.9 (98.7–99.1)	98.7 (98.1–99.3)	.52
Yes	163	1.2 (1.0–1.3)	1.1 (0.9–1.3)	1.3 (0.7–1.9)	.52
Other substance use					
0	11 496	84.2 (83.6–84.8)	84.2 (83.6–84.9)	83.9 (82.0–85.8)	.72
1	1708	12.5 (11.9–13.1)	12.3 (11.7–13.0)	13.7 (12.0–15.5)	.13
2+	447	3.3 (3.0–3.6)	3.4 (3.1–3.8)	2.4 (1.7–3.1)	.01
Online engagement					
No	12 024	88.2 (87.6–88.7)	88.0 (87.4–88.7)	89.0 (87.4–90.6)	.24
Yes	1627	11.8 (11.3–12.4)	12.0 (11.3–12.6)	11.0 (9.4–12.6)	.24
Tobacco use status					
Tobacco never-users	10 246	78.2 (77.4–78.9)	78.6 (77.8–79.4)	75.3 (73.1–77.6)	.005
Tobacco ever-users	2868	21.8 (21.1–22.6)	21.4 (20.6–22.2)	24.7 (22.4–26.9)	.005
Past-y single product users	936	6.9 (6.5–7.4)	6.7 (6.3–7.2)	8.0 (6.6–9.4)	.07
Past-y tobacco users	2175	16.1 (15.4–16.7)	15.7 (15.0–16.4)	18.3 (16.4–20.3)	.01

days a respondent used the product multiplied by the number of uses per day. The PATH Study ascertained past 30-day frequency of hookah use differently than other products. We defined total hookah consumption as frequency of use among monthly users, 4 times weekly frequency among weekly users, and 30 times daily frequency among daily users. We considered a respondent to have increased frequency of use if total consumption increased between baseline and follow-up. Third, we considered a respondent to have progressed to poly-product use if she or he reported using only 1 product within the past 12 months at baseline and using ≥ 2 products within the past 12 months at follow-up. Fourth, we considered a respondent to have quit if she or he reported use of ≥ 1 product within the past 12 months at baseline and reported not using any products within the past 12 months at follow-up.

Primary Variable of Interest

The primary variable of interest was engagement with online tobacco marketing. We considered a respondent to have engaged if she or he responded affirmatively to ≥ 1 of 10 forms of engagement. See Supplemental Table 6 for details on the forms of engagement.

Covariates

We assessed sociodemographic characteristics of respondents including age at baseline, sex, race and/or ethnicity, and parental education. Environmental characteristics included weekly income and school performance. Internet and social networking use behavior included frequency of Internet access and social networking account use, as well as use of a smartphone. Behavioral characteristics included the level of sensation seeking and mental health status. We assessed the level of sensation seeking as the mean of 3 items modified from the Brief Sensation Seeking Scale measured on a 5-point Likert scale.¹⁷ We assessed mental health status by internalizing and externalizing problem levels, which were respectively the sum of 4 and 5 items based on the Global Appraisal of Individual Needs-Short Screener.¹⁸ We assessed whether respondents lived with anyone who currently used tobacco. Respondents' exposures to tobacco coupons or other tobacco-related information via mail were assessed, as was other substance use including past 30-day binge alcohol drinking, past-year marijuana use, and past-year illicit and nonprescription drug use. We categorized baseline never-users as susceptible to tobacco use on the

basis of intention to use a tobacco product soon, willingness to try a product if offered by a friend, and curiosity about using a product.¹⁹ See Supplemental Table 6 for details on all covariates.

Analyses

First, we estimated the prevalence characteristics among all baseline respondents, baseline respondents with follow-up, and baseline respondents without follow-up. We tested for equality of prevalence by using the weighted *t* test statistic. Second, we estimated the prevalence of each form of engagement among baseline respondents with follow-up. Third, we assessed (by engagement) the proportion of: (1) baseline never-users who initiated tobacco use at follow-up; (2) baseline single-product users who progressed to poly-product use at follow-up; (3) baseline never- or ever-users who increased frequency of product use at follow-up; and (4) baseline past-year tobacco product users who had quit at follow-up. We tested for equality of proportions by using the Pearson χ^2 statistic.

Fourth, with engagement with online tobacco marketing as the predictor variable of interest, we fit weighted multivariable logistic regression models for each tobacco-related transition: initiation,

TABLE 2 Weighted Prevalence of Engagement With Online Tobacco Marketing Among Adolescents

Form of Online Engagement	Count	Prevalence, % (95% CI)
Signed up for e-mail alerts, read articles online, and/or watched videos online about tobacco products	605	4.6 (4.2–4.9)
Used a smartphone to scan a QR code for a tobacco product or to enter a sweepstakes or drawing from a tobacco company	395	2.9 (2.6–3.2)
Visited a tobacco Web site in the past 6 mo	326	2.3 (2.0–2.6)
Received discount coupons via e-mail, the Internet, social networks, or a text message	321	2.2 (2.0–2.5)
Liked or followed a tobacco company on Facebook, Twitter, or other sites	218	1.5 (1.3–1.7)
Played an online game related to a tobacco company	161	1.1 (0.9–1.3)
Sent a link or information about a tobacco company to others on Facebook, Twitter, or other sites	110	0.8 (0.7–1.0)
Received other tobacco-related information via e-mail, the Internet, social networks, or a text message	126	0.8 (0.6–0.9)
Used a smartphone to scan a QR code for a tobacco product that took the respondent to a tobacco company Web site	46	0.3 (0.2–0.5)
Registered at a tobacco company Web site	38	0.2 (0.2–0.3)
Reported ≥ 1 form of online engagement	1627	11.8 (11.3–12.4)

Among Wave 1 respondents with follow-up.

increased frequency, progression, and cessation. We adjusted for sociodemographic, environmental, and behavioral characteristics; Internet and social networking behavior; exposure to tobacco use; offline tobacco marketing; and other substance use.

Fifth, we conducted additional analyses to determine if the relationship between baseline engagement was specific to tobacco-related outcomes (eg, tobacco use initiation) or also associated with other high-risk behaviors, such as past-month binge drinking. We began with respondents who reported no binge drinking within the past 30 days and fit a weighted multivariable logistic regression model with past 30-day binge drinking at follow-up as the outcome. Covariates included engagement; sociodemographic, environmental, and behavioral characteristics; Internet and social networking behavior; exposure to tobacco use; offline marketing; other substance use; and ever-tobacco use. Finally, we estimated the population attributable fraction (PAF) of engagement and each tobacco-related outcome, assuming a causal association.¹⁵ For example, the PAF for an adverse outcome (eg, initiation) equals the proportion of that outcome that could be eliminated if engagement were eliminated while all other risk factors remained constant.²⁰ Conversely,

the PAF for a desired outcome (eg, cessation) indicates how much that outcome could be increased if engagement were eliminated.

We stratified the multivariable analysis between engagement and tobacco use initiation by susceptibility to tobacco use among never-users and conducted a post hoc analysis to determine if the nonsusceptible never-user sample size was sufficiently large to achieve statistical power in excess of 95%.²¹

Throughout all analyses, we used balanced repeated replication weights with Fay's correction (shrinkage factor set at 0.3). For multivariable regression models, we used complete case analysis. The percentage of missing data among covariates ranged from 0% to 5.0%. We used a computer program (R, version 3.4.1; The R Foundation, Vienna, Austria) for all statistical analyses. Additionally, we used the following R packages: survey (version 3.31-2) to estimate the weighted prevalence of engagement and conduct the multivariable analysis, weights (version 0.85) to test for equality of weighted prevalence of sample characteristics between respondents retained for analysis and respondents lost to follow-up, and AF (version 0.1.4) to estimate the attributable fraction of engagement and each tobacco-related outcome.

RESULTS

Study Population

The baseline sample distribution was approximately even between younger and older adolescents (50.4% of 12–14 year olds and 49.6% of 15–17 year olds; Table 1). The baseline sample was 51.3% boys, 54.5% non-Hispanic white, 22.3% Hispanic, and 13.9% non-Hispanic African American. The majority of respondents accessed the Internet and used a social networking account at least once per day (77.2% and 63.2%, respectively). Approximately 1 in 3 respondents (34.6%) currently lived with a tobacco user. At baseline, 78.2% had never used tobacco products, 6.9% had used a single product within the past year, and 16.1% had used at least 1 product within the past year.

Nearly 12% of respondents engaged with 1 or more forms of online marketing (Table 2). The 3 most frequent forms were: (1) signing up for e-mail alerts about tobacco products, reading articles online about tobacco products, or watching a video online about tobacco products; (2) using a smartphone to scan a quick response (QR) code for a tobacco product or to enter a sweepstakes or drawing from a tobacco company; and (3) visiting a tobacco company Web site in the past 6 months.

TABLE 3 Incidence of Tobacco Use Initiation, Increased Frequency of Tobacco Use, Progression to Poly-Tobacco Product Use, and Tobacco Use Cessation by Baseline Engagement With Online Tobacco Marketing

		Tobacco Use Initiation ^a			Increased Frequency of Tobacco Use ^b		
		No	Yes	<i>P</i>	No	Yes	<i>P</i>
Online engagement	No	<i>N</i> = 7232	<i>N</i> = 957	<.001	<i>N</i> = 10 088	<i>N</i> = 463	<.001
		88.1%	11.9%		95.6%	4.4%	
	(87.4%–88.9%)	(11.1%–12.6%)	(95.2%–96.0%)		(4.0%–4.8%)		
	<i>N</i> = 712	<i>N</i> = 166	<i>N</i> = 1294		<i>N</i> = 151		
Yes	80.5%	19.5%	89.7%	10.3%			
	(77.7%–83.3%)	(16.7%–22.3%)	(88.0%–91.3%)	(8.7%–12.0%)			
		Progression to Poly-Tobacco Product Use ^c			Tobacco Use Cessation ^d		
Online engagement	No	<i>N</i> = 9516	<i>N</i> = 227	<.001	No	Yes	<i>P</i>
		97.6%	2.4%		No	Yes	<i>P</i>
	(97.3%–97.9%)	(2.1%–2.7%)	(76.3%–80.7%)		(19.3%–23.7%)		
	<i>N</i> = 1125	<i>N</i> = 60	<i>N</i> = 339		<i>N</i> = 68		
Yes	94.2%	5.8%	83.9%	16.1%			
	(92.8%–95.7%)	(4.3%–7.2%)	(80.2%–87.6%)	(12.4%–19.8%)			

Each cell contains the count, point estimate of the incidence, and CI of the incidence (within parentheses). All percentages are weighted. The *P* value is based on weighted χ^2 tests.

^a Among baseline tobacco never-users (*N* = 9067 respondents with follow-up).

^b Among baseline tobacco never- and ever-users (*N* = 11 996 respondents with follow-up).

^c Among baseline tobacco never-users and single tobacco product users (*N* = 10 928 respondents with follow-up).

^d Among baseline past-year tobacco users (*N* = 1869 respondents with follow-up).

Among never-users at baseline, 19.5% of adolescents who engaged with online tobacco marketing initiated tobacco use at follow-up compared with 11.9% of adolescents who did not engage (*P* < .001, Table 3). Among all respondents, 10.3% of adolescents who engaged increased frequency of tobacco use, compared with 4.4% of adolescents who did not engage (*P* < .001). Among past-year single-product users at baseline, 5.8% of adolescents who engaged progressed to poly-product use compared with 2.4% of adolescents who did not engage (*P* < .001). Finally, among past-year tobacco product users at baseline, 16.1% of adolescents who engaged had quit at follow-up compared with 21.5% of adolescents who did not engage (*P* = .02).

Multivariable Analyses

Adjusting for demographic, psychosocial, and behavioral characteristics, the odds of tobacco use initiation were higher for adolescents who engaged than for adolescents who did not (adjusted odds ratio [aOR] = 1.26; 95% confidence interval [CI]: 1.01–1.57; Table 4). Similarly, the odds of

increased frequency of tobacco product use were higher for adolescents who engaged than for adolescents who did not (aOR = 1.58; 95% CI: 1.24–2.00), as were odds of progression to poly-product use (aOR = 1.70; 95% CI: 1.20–2.43). In contrast, the odds of cessation were lower for adolescents who engaged than for adolescents who did not (aOR = 0.71; 95% CI: 0.50–1.00). In addition to engagement, adolescents who currently lived with a tobacco user had higher odds of initiation, increased frequency of use, and progression to poly-product use, and lower odds of tobacco cessation than adolescents who did not live with a tobacco user. We observed similar associations with use of other substances. Finally, we observed no significant relationship between engagement and initiation of binge alcohol drinking (aOR = 0.89; 95% CI: 0.60–1.30; Supplemental Table 5).

We stratified the analysis between engagement and tobacco use initiation by susceptibility. The prevalence of engagement among susceptible never-users exceeded that of nonsusceptible never-users: 13.9% (95% CI: 12.8%–15.0%) and 6.2% (95% CI: 5.5%–6.8%),

respectively (Supplemental Table 7). Among susceptible never-users, the odds of tobacco use initiation were higher, although not significantly so, for adolescents who engaged than for those who did not (aOR = 1.23; 95% CI: 0.96–1.58; Supplemental Table 8). Among nonsusceptible never-users, the odds of initiation were lower, although not significantly so, for adolescents who engaged than for those who did not (aOR = 0.83; 95% CI: 0.49–1.40). In our post hoc analyses, we concluded that the sample sizes of nonsusceptible and susceptible adolescents were both sufficiently large to achieve respective powers >99%.

To quantify the public health burden of engagement with online tobacco marketing, we estimated the PAF of engagement on the 4 tobacco-related outcomes studied. If engagement were eliminated, initiation, increased frequency, and progression could decrease by 1.5%, 7.6%, and 4.4%, respectively, and cessation could increase by 4.8% (Fig 1).

DISCUSSION

In this longitudinal analysis, we report 2 central findings. First,

TABLE 4 Multivariable Logistic Regression Analyses of Tobacco Use Initiation, Progression to Poly-Tobacco Product Use, and Tobacco Use Cessation

Covariate	Model, aOR (95% CI)			
	Tobacco Use Initiation ^a	Increased Frequency of Tobacco Use ^b	Progression to Poly-Tobacco Product Use ^c	Tobacco Use Cessation ^d
Online engagement (reference: no)	1.26 (1.01–1.57)	1.58 (1.24–2.00)	1.70 (1.20–2.43)	0.71 (0.50–1.00)
15–17 y (reference: 12–14 y)	1.88 (1.62–2.19)	1.10 (0.88–1.37)	3.44 (2.43–4.87)	0.54 (0.39–0.74)
Male (reference: female)	1.10 (0.94–1.28)	1.27 (1.04–1.55)	1.37 (1.03–1.83)	0.82 (0.61–1.10)
Race and/or ethnicity (reference: non-Hispanic white)				
Hispanic	0.97 (0.81–1.17)	0.65 (0.51–0.83)	0.77 (0.54–1.10)	1.90 (1.39–2.59)
Non-Hispanic African American	0.62 (0.49–0.79)	0.36 (0.24–0.53)	0.48 (0.30–0.77)	3.26 (2.16–4.93)
Non-Hispanic other	0.85 (0.64–1.13)	0.50 (0.35–0.73)	0.60 (0.35–1.03)	1.56 (0.98–2.49)
Parental education (reference: at least some college)				
High school graduate	1.07 (0.88–1.29)	1.46 (1.15–1.85)	1.45 (1.03–2.03)	1.08 (0.77–1.52)
Less than high school	1.05 (0.85–1.29)	1.08 (0.83–1.40)	1.04 (0.71–1.53)	1.18 (0.84–1.65)
Weekly income, \$ (reference: none or <1)				
1–20	1.31 (1.10–1.55)	1.41 (1.11–1.79)	1.55 (1.08–2.23)	0.73 (0.52–1.02)
21–50	1.38 (1.06–1.79)	1.35 (0.96–1.89)	2.14 (1.36–3.35)	0.56 (0.37–0.86)
51+	1.98 (1.54–2.55)	1.24 (0.89–1.73)	2.91 (1.92–4.41)	0.57 (0.38–0.86)
School performance (reference: mostly As)				
As and Bs	1.37 (1.12–1.67)	1.89 (1.35–2.66)	1.29 (0.84–1.98)	1.21 (0.79–1.85)
Mostly Bs	1.43 (1.07–1.93)	1.51 (0.95–2.39)	2.22 (1.32–3.72)	0.99 (0.58–1.68)
Bs and Cs	1.84 (1.45–2.33)	3.44 (2.43–4.87)	2.19 (1.38–3.46)	0.75 (0.48–1.18)
Mostly Cs to mostly Fs	2.64 (2.01–3.47)	5.03 (3.50–7.22)	2.79 (1.71–4.56)	0.67 (0.41–1.08)
School ungraded	1.76 (0.52–5.95)	1.92 (0.60–6.17)	6.87 (2.38–19.88)	0.41 (0.07–2.49)
Internet access (reference: several times a d)				
Approximately once a day	1.37 (1.10–1.70)	1.23 (0.90–1.67)	0.84 (0.54–1.33)	1.57 (1.05–2.36)
3–5 d a wk	1.13 (0.86–1.48)	1.38 (1.01–1.87)	1.29 (0.80–2.09)	1.00 (0.65–1.54)
1–2 d a wk	1.34 (0.91–1.96)	1.13 (0.65–1.98)	0.53 (0.19–1.50)	1.06 (0.44–2.60)
Less than once a wk	1.52 (1.06–2.16)	1.33 (0.84–2.10)	1.11 (0.53–2.34)	0.94 (0.47–1.88)
Social networking account use (reference: several times a day)				
Daily	0.69 (0.58–0.83)	0.79 (0.63–1.00)	0.64 (0.46–0.90)	1.12 (0.83–1.52)
Weekly	0.61 (0.48–0.77)	0.77 (0.56–1.06)	0.87 (0.55–1.37)	0.67 (0.42–1.07)
Monthly or less	0.42 (0.33–0.54)	0.47 (0.33–0.66)	0.54 (0.33–0.88)	0.74 (0.45–1.22)
Use smartphone (reference: no)	1.42 (1.17–1.71)	1.12 (0.86–1.44)	1.18 (0.81–1.71)	0.97 (0.66–1.42)
Sensation seeking (reference: low)				
Moderate	1.14 (0.94–1.39)	1.25 (0.94–1.66)	1.11 (0.75–1.64)	1.08 (0.74–1.58)
High	2.01 (1.65–2.47)	2.02 (1.51–2.70)	2.16 (1.47–3.19)	0.86 (0.59–1.26)
Internalizing (reference: low)				
Moderate	1.16 (0.94–1.42)	0.84 (0.63–1.12)	0.92 (0.62–1.36)	1.17 (0.79–1.74)
High	1.32 (1.06–1.64)	0.94 (0.69–1.27)	1.23 (0.84–1.82)	1.04 (0.68–1.58)
Externalizing (reference: low)				
Moderate	1.37 (1.08–1.73)	0.94 (0.67–1.32)	1.15 (0.73–1.80)	0.76 (0.49–1.18)
High	1.56 (1.22–2.00)	1.34 (0.95–1.89)	1.23 (0.77–1.94)	0.74 (0.47–1.14)
Currently lives with a tobacco user (reference: no)	1.59 (1.36–1.85)	1.74 (1.42–2.13)	1.60 (1.21–2.11)	0.76 (0.58–1.00)
Exposed to tobacco coupons by mail (reference: no)	0.71 (0.49–1.01)	0.82 (0.56–1.20)	0.72 (0.42–1.23)	0.91 (0.52–1.60)
Exposed to other tobacco information by mail (reference: no)	1.07 (0.51–2.24)	1.07 (0.57–2.03)	2.17 (0.70–6.76)	2.25 (0.74–6.81)
Other substance use (reference: 0)				
1	1.85 (1.48–2.32)	2.50 (1.98–3.15)	3.41 (2.53–4.60)	0.54 (0.41–0.71)
2+	6.37 (3.34–12.15)	2.63 (1.87–3.71)	5.32 (2.82–10.05)	0.25 (0.16–0.40)

^a Among the 9067 tobacco never-users at baseline with follow-up.

^b Among the 11 996 tobacco never- and ever-users at baseline with follow-up.

^c Among the 10 928 tobacco never-users and single-product tobacco users at baseline with follow-up.

^d Among the 1869 past-year tobacco users at baseline with follow-up.

engagement with online tobacco marketing was associated with higher incidences of tobacco use initiation, increased frequency of use, and progression to poly-product use, and a lower incidence of cessation. Second, engagement with online tobacco marketing was associated

with lower incidence of tobacco use cessation. Our study contributes to an established body of evidence on adolescents and tobacco-related marketing, which has consistently concluded that exposure to

marketing leads to tobacco use initiation and progression.^{15,22–30} These earlier longitudinal studies assessed adolescent exposure to tobacco marketing through traditional channels, such as billboards, magazines, and retail point-of-sale. Unlike exposure to

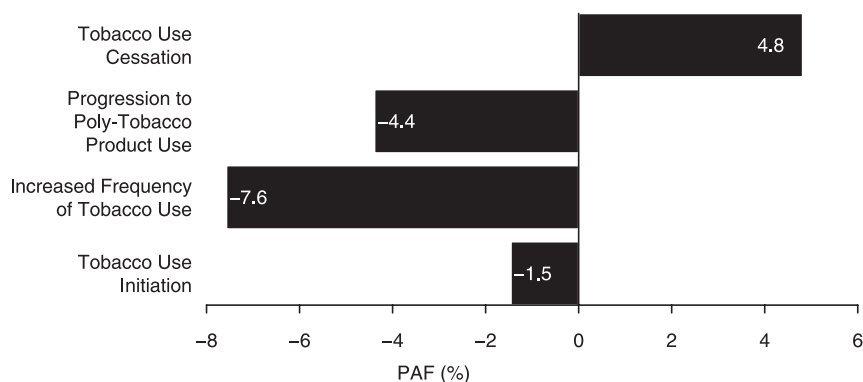


FIGURE 1 PAF of engagement with online tobacco marketing and tobacco use initiation, increased frequency of tobacco use, progression to poly-tobacco product use, and cessation.

traditional marketing channels, exposure to online tobacco marketing has increased over time for adolescents.³¹

Active engagement with online marketing may be even more problematic than passive exposure to traditional marketing for adolescents because engagement increases advertising effectiveness.¹³ Several leading forms of online engagement, such as watching videos online about tobacco products, involve social networking sites. Social networking sites may influence adolescents more than traditional media because adolescents create and consume content for and from their peers.^{32,33} Many sites allow users to endorse content (eg, “like” on Facebook). The authors of a recent functional magnetic resonance image–based study found adolescent participants were more likely to endorse photos of risky behaviors, such as cigarette smoking, if those photos received more peer endorsement.³⁴ As peer endorsement increased, brain activity increased, notably in areas responsible for social cognition and memories.³⁴ This increased activity is troubling because a significant proportion of adolescent engagement occurs via social networking sites.¹⁴

Several reasons may explain the longitudinal association between engagement and tobacco use

initiation, increased frequency of use, progression to poly-product use, and use cessation. Engagement may directly influence adolescents by changing perceived norms and risks regarding tobacco use.^{35,36} Engagement could also indirectly influence adolescents by altering peer networks, modeling tobacco use behaviors after those depicted in marketing, and increasing positive smoking expectancies.^{37–39} Price discounts resulting from engagement may enable adolescents to purchase tobacco products at reduced prices.

Additionally, engagement may generate curiosity about tobacco products. Tobacco companies commonly use curiosity-generating advertising that precede product information advertisements. This strategy has been shown empirically to increase product affect and interest, unaided brand recall, and time viewing the advertisement.^{40,41} For example, the summer 2017 Blu e-cigarette marketing campaign engendered curiosity by posing the question, “Which blu is right for you? Based on your personal style, we’ll match you with the perfect e-cig and a special offer!”⁴² Viewers then completed a short quiz with graphic interchange formats and memes from popular television shows. Product information advertisements followed in a separate e-mail.

Our stratification results suggest but do not confirm that the longitudinal association between engagement and tobacco use initiation was stronger for susceptible never-users than for nonsusceptible never-users. Susceptible adolescents may engage with online tobacco marketing to satisfy existing curiosity about specific tobacco products, and this engagement may prompt adolescents to act on their curiosity. Previous research concluded engagement with alcohol brand marketing promoted changes in attitudinal susceptibility, which increased likelihood of binge drinking initiation.⁴³

Adolescent engagement could decrease through effective regulation and cooperation from social networking sites. The 2009 Family Smoking Prevention and Tobacco Control Act granted the FDA regulatory authority over tobacco product marketing, with e-cigarettes included in 2016. To date, the FDA has not instituted any significant regulation over online tobacco marketing, perhaps because of concern that the tobacco industry would challenge any regulation as violating its First Amendment protection of commercial speech. Yet, restrictions on commercial speech may not violate constitutional protections if the FDA mandated the tobacco industry to only advertise to verified adult tobacco users.⁴⁴ Regulation of user-generated content on social media presents additional challenges because such speech is constitutionally protected.⁴⁵ However, social media sites can and do regulate content generated by users.⁴⁶ For example, YouTube could age-restrict or delete (in accordance with its policies) videos of adults demonstrating vaping tricks because adolescents could easily access and imitate the acts. Twitter could detect and remove automated or promotional tweets generated by commercial bots for violating

the terms of service prohibiting spamming.

This longitudinal study has several strengths. First, our study establishes a temporal order of engagement and changes in tobacco use. Second, we use data from a large, nationally representative longitudinal study of US adolescents. Third, loss to follow-up (12.1%) was low, with respondents lost and not lost being equally likely to engage. Thus, we may conservatively estimate the longitudinal association between engagement and tobacco use initiation if respondents lost to follow-up were more likely to initiate than respondents not lost to follow-up. Similarly, we may conservatively estimate longitudinal associations between engagement and progression and engagement and cessation if respondents lost to follow-up were more likely to progress and less likely to quit, respectively.

We note several important limitations. First, we do not know if engagement directly or indirectly affects tobacco use initiation through changes in attitudinal susceptibility, specifically curiosity. Curiosity could lead to or result from engagement, and either could increase the risk of initiation. On the basis of additional PATH study waves, future research can determine the precise and likely reciprocal relationship between engagement and susceptibility on initiation. Second, we could not assess respondents' exposure

to retail tobacco marketing (eg, convenience stores) because the Wave 1 PATH study did not address this marketing channel. Third, our study may underestimate participants' recall of engagement because PATH study survey items specifically mentioned only 2 social networking sites (Facebook and Twitter), whereas other sites (eg, Instagram) were included as a residual category ("...or other sites"). Fourth, several covariates were missing a small percentage of data. We performed multiple imputations to address this missing data, fit the same regression models on multiple imputed data sets, and reached the same substantive conclusions as the complete case analysis. Finally, the PATH study ascertained information on 5 tobacco brands: 3 cigarette brands (Marlboro, Camel, and Newport), 1 cigar brand (Swisher), and 1 e-cigarette brand (Blu). Although these brands represented a large share of the market for each product, our study may conservatively estimate level of engagement.⁴⁷⁻⁴⁹ Moreover, these data may not fully capture the nuanced nature of marketing effects, including product- or brand-specific effects, as well as the effect of specific marketing claims and appeals.

CONCLUSIONS

Adolescent engagement with online tobacco marketing represents a public health problem through

increased risk of (1) initiation of tobacco use, (2) increased frequency of tobacco product use, and (3) progression to poly-tobacco product use, as well as through decreased likelihood of tobacco use cessation. Although the FDA has had regulatory authority over tobacco product marketing since 2009, important regulatory gaps remain regarding online marketing. Effective regulation to limit adolescents' engagement with online tobacco marketing would require active cooperation of social networking sites. Ultimately, lower engagement could mitigate the future population burden of tobacco use by reducing the number of adolescents who initiate tobacco use and increasing the number who quit.

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ABBREVIATIONS

aOR: adjusted odds ratio
CI: confidence interval
FDA: Food and Drug Administration
PAF: population attributable fraction
PATH: Population Assessment for Tobacco and Health
QR: quick response

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Online Tobacco Marketing and Subsequent Tobacco Use

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