Adolescent E-Cigarette, Hookah, and Conventional Cigarette Use and Subsequent Marijuana Use

Janet Audrain-McGovern, PhD, a Matthew D. Stone, BA, b Jessica Barrington-Trimis, PhD, b Jennifer B. Unger, PhD, b Adam M. Leventhal, PhD, c

OBJECTIVES: Noncigarette tobacco products may confer a risk of marijuana use similar to combustible cigarettes. We examined whether adolescent electronic cigarette (e-cigarette), hookah, or combustible cigarette use is associated with initiating and currently using marijuana as well as using both tobacco and marijuana concurrently.

METHODS: Adolescents from 10 public schools in Los Angeles, California, completed in-classroom surveys at baseline (fall 2013, ninth grade) and at a 24-month follow-up (fall 2015, 11th grade). Among adolescents who never used marijuana at baseline (N = 2668), associations of baseline e-cigarette, hookah, or combustible cigarette use with ever marijuana use (initiation), current marijuana use (past 30 days), and current dual use of marijuana and these tobacco products at the 24-month follow-up were examined.

RESULTS: Baseline ever versus never e-cigarette use was associated with initiation (odds ratio [OR] 3.63; 95% confidence interval [CI] 2.69–4.90) and current (OR 3.67; 95% CI 2.51–5.36) marijuana use 24 months later. Ever versus never hookah use was associated with initiation (OR 3.55; 95% CI 2.49–5.08) and current (OR 4.10; 95% CI 2.69–6.25) marijuana use 24 months later. Similar associations were observed for combustible cigarette smoking and initiation (OR 4.30; 95% CI 2.79–6.63) and current use of marijuana (OR 1.97; 95% CI 1.05–3.68). Current use of any of these tobacco products at baseline was associated with current use of both tobacco and marijuana (OR 2.28; 95% CI 1.47–3.55) 24 months later.

CONCLUSIONS: The association between tobacco use and subsequent marijuana use across adolescence extends to multiple tobacco products.
Combustible cigarette smoking is associated with the initiation of marijuana use, earlier onset of marijuana use, more rapid escalation in use, and the development of nicotine and cannabis dependence.\cite{1,4}

The adverse health consequences of cigarette smoking and marijuana use have been documented,\cite{5,6} with more severe and persistent negative outcomes seen when use is initiated during adolescence and when both substances are used.\cite{1,7,8}

Although adolescent cigarette smoking has declined significantly over the past decade,\cite{9} approximately one-third of US adolescents report currently using at least 1 tobacco product, an increase of 35% since 2011.\cite{9} This increase is attributable to the use of alternative nicotine-delivery products, such as electronic cigarettes (e-cigarettes) and hookah.\cite{10,11} More than 11% of high school students currently use e-cigarettes,\cite{12} and an estimated 5% to 11% currently smoke hookah.\cite{12–15}

Whether the well-established comorbidity between combustible cigarette smoking and subsequent marijuana use in adolescence translates to e-cigarette and hookah use is unknown.

Data revealing that the use of e-cigarettes and hookah are associated with risk of adolescent marijuana use and co-use would be important evidence for guiding marijuana and tobacco policies to protect adolescent health.\cite{10,16}

The diversity of marijuana products, such as vaporized and edible forms, offers more opportunities for co-use. In addition, if use of e-cigarettes and hookah increases the likelihood of marijuana use, the health risks of increased youth marijuana use should be included in models of the net population effects of alternative tobacco products.\cite{17}

We examined whether adolescent use of e-cigarettes and hookah is associated with the risk of initiating and regularly using marijuana as well as using both substances among high school students from ages 14 to 16 years.

**METHODS**

**Participants and Procedure**

Data were collected as part of a longitudinal survey of substance use and mental health among high school students in Los Angeles, California. Approximately 40 public high schools in the Los Angeles metropolitan area were approached about participating in this study; these schools were chosen because of their diverse demographic characteristics and proximity. Ten schools agreed to participate in the study. To enroll in the study, students and their parents were required to provide active written or verbal assent and consent, respectively. Data collection involved 5 assessment waves that took place ~6 months apart: baseline (fall 2013, ninth grade), 6-month follow-up (spring 2014, ninth grade), 12-month follow-up (fall 2014, 10th grade), 18-month follow-up (spring 2015, 10th grade), and 24-month follow-up (fall 2015, 11th Grade). Waves 1 and 5 are the focus of this investigation because current use of all forms of marijuana was assessed at wave 5. At each wave, paper-and-pencil surveys were administered in students’ classrooms. Students who were absent completed an interviewer-administered phone survey or a Web-based survey. The University of Southern California Institutional Review Board approved the study.

**Measures**

Each measure described below has been shown to have adequate psychometric properties in adolescent samples.\cite{9,18–20}

**Tobacco Product Use and Marijuana Use**

At baseline and the 24-month follow-up, items based on the Youth Risk Behavior Surveillance Survey\cite{9,18} were used to assess ever use and current use (past 30-day use; yes or no) of e-cigarettes, combustible cigarettes, and a hookah water pipe; use of any type of marijuana product at baseline; and use of 3 different marijuana products (combustible, vaped, and edible) at follow-up. Responses to the baseline questions of ever tobacco use (combustible cigarette, e-cigarette, and hookah) served as the primary exposure variable. Outcomes were ever use (yes or no) and current use (past 30-day use; yes or no) of (1) combustible marijuana, (2) vaped marijuana, and (3) edible marijuana. The terms “ever-marijuana users” and “never-marijuana user” are used to refer to adolescents who ever and never used any of the 3 forms of marijuana, respectively.

The relationship between other tobacco products (e.g., smokeless tobacco and cigars) and marijuana were not examined because of a low prevalence of use and because we were interested in evaluating novel associations between newer tobacco products and marijuana.

**Covariates**

Variables that potentially overlapped with the risk for tobacco use and the risk of marijuana use were selected a priori as covariates on the basis of previous studies.\cite{20–26} Covariates included sociodemographic, environmental, and interpersonal variables.

**Sociodemographics**

Sociodemographic characteristics, including age, sex, ethnicity, race, and highest parental education, were assessed by using self-report items.

**Environmental Factors**

Indicators of the proximal environment included family living situation, which was measured with the item, “Who do you live with most of the time?” (both biological parents versus other).\cite{22} Family history of smoking was measured by using
the question, “Does anyone in your immediate family (brothers, sisters, parents, and/or grandparents) have a history of smoking cigarettes?” (yes or no). Peer smoking was assessed with responses to the item, “In the last 30 days, how many of your 5 closest friends have smoked cigarettes?” (range: 0–5).9 Similar questions were used to measure family history of substance and peer marijuana use.

**Intrapersonal Factors**

Affective and self-regulatory psychological processes linked with tobacco use, marijuana use, and other risky behaviors were assessed. Depressive symptoms were measured by using the 20-item Center for Epidemiologic Studies Depression Scale (CESD).19 Composite sum past-week frequency rating (eg, 0 = rarely or none of the time [0–1 day] to 3 = most or all of the time [5–7 days]). Impulsivity was measured with the 5-item Temperament and Character Inventory (TCI) Impulsivity subscale sum score, which is used to assess tendency toward acting on instinct without conscious deliberation (eg, “I often do things based on how I feel at the moment”; range: 0–5).20

**Statistical Analysis**

Multinomial polytomous regression models were used to test the association between baseline tobacco product use and marijuana product use 24 months later across 3 outcome categories: (0) never use, (1) past use (ie, initiated or ever use but no use in the past 30 days), and (2) current use (ie, use in the past 30 days). Adolescents who reported no marijuana use at baseline formed the sample for analyses. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated to estimate the risk of past or current use of each marijuana product in relation to never use. Separate unadjusted models were used for each predictor (combustible cigarettes, e-cigarettes, hookah, and any of these products). School-level clustering was recoded to the district level and entered as a fixed effect because of the low prevalence of current marijuana vaping at 1 of the participating schools. Variables listed in Table 1, including sociodemographic, environmental, and interpersonal factors that are linked to adolescent tobacco and marijuana use, were added in subsequent separate adjusted models as potential confounders.

To assess the unique effects of each individual tobacco product, a set of combined polytomous regression models were run, in which lifetime use of e-cigarettes, hookah, and combustible cigarettes were included as simultaneous predictors to elucidate the incremental effect of each product after controlling for their covariance with one another. Missing data on covariates were handled by using multiple imputation with the Markov Chain Monte Carlo method of data augmentation.27–29

Continuous variables were rescaled (mean = 0; SD = 1) for regression models to facilitate interpretation. Analyses were conducted by using IBM SPSS Statistics for Windows version 24.0 (IBM SPSS Statistics, IBM Corporation, Armonk, NY). Significance was set to .05, and all tests were 2 tailed.

**RESULTS**

**Study Sample**

All ninth-grade English-speaking students who were not in special education (eg, because of severe learning disabilities) were eligible to participate (N = 4100). Of the assenting students (N = 3874; 94.5%), 3396 (87.7%) provided parental consent, from whom data were collected for 3383 (99.6%) at baseline and 3232 (95.2%) 24 months later. The sample was limited to those adolescents who provided data on lifetime tobacco product use, lifetime marijuana use, marijuana product use at follow-up, and those

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**TABLE 1 Sample Characteristics of Ninth-Grade Never-Marijuana Users (N = 2688) by Baseline Ever-Tobacco Use Status**

<table>
<thead>
<tr>
<th>Baseline Characteristics</th>
<th>Total (N = 2688)</th>
<th>Baseline Tobacco Product Use</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Never (n = 2188)</td>
<td>Ever (n = 480)</td>
<td></td>
</tr>
<tr>
<td>Sex, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>1450 (54.3)</td>
<td>1205 (55.1)</td>
<td>.11b</td>
</tr>
<tr>
<td>Male</td>
<td>1218 (45.7)</td>
<td>983 (44.9)</td>
<td></td>
</tr>
<tr>
<td>Age, mean (SD)</td>
<td>14.56 (0.40)</td>
<td>14.55 (0.39)</td>
<td>.10c</td>
</tr>
<tr>
<td>Race and/or ethnicity, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>1184 (45.3)</td>
<td>988 (44.7)</td>
<td>.12c</td>
</tr>
<tr>
<td>Asian American</td>
<td>627 (23.8)</td>
<td>534 (24.7)</td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>448 (17.0)</td>
<td>372 (17.2)</td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>130 (4.9)</td>
<td>106 (4.9)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>237 (9.0)</td>
<td>186 (8.6)</td>
<td></td>
</tr>
<tr>
<td>Parental college education, n (%)</td>
<td>1247 (53.6)</td>
<td>1060 (55.5)</td>
<td>&lt;.001b</td>
</tr>
<tr>
<td>Environmental factors, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lives with both biological parents</td>
<td>1786 (67.2)</td>
<td>1501 (68.8)</td>
<td>&lt;.001b</td>
</tr>
<tr>
<td>Family history of smoking</td>
<td>1580 (61.7)</td>
<td>1251 (59.5)</td>
<td>&lt;.001b</td>
</tr>
<tr>
<td>Family history of drug use</td>
<td>399 (15.6)</td>
<td>300 (14.3)</td>
<td>&lt;.001b</td>
</tr>
<tr>
<td>Peer combustible cigarette use</td>
<td>332 (12.7)</td>
<td>221 (10.3)</td>
<td>&lt;.001b</td>
</tr>
<tr>
<td>Peer marijuana use</td>
<td>698 (26.7)</td>
<td>468 (21.8)</td>
<td>&lt;.001b</td>
</tr>
<tr>
<td>Interpersonal factors, mean (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TCI Impulsivity subscale</td>
<td>2.45 (1.47)</td>
<td>2.34 (1.49)</td>
<td>.004c</td>
</tr>
<tr>
<td>CESD</td>
<td>14.04 (11.44)</td>
<td>13.31 (10.99)</td>
<td>16.88 (12.45)</td>
</tr>
</tbody>
</table>

a Totals vary because of missing values.  
b Calculated by using the χ² test.  
c Calculated by using the independent samples t test.

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who had never used marijuana at baseline (N = 2668). The sample characteristics are summarized in Table 1. There were positive associations between ever use of tobacco products at baseline and all environmental and interpersonal characteristics (Table 1).

### Table 1: Baseline Never-Marijuana Users

<table>
<thead>
<tr>
<th>Baseline Regressors</th>
<th>Marijuana Product Use at 24-Mo Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Combustible Marijuana</td>
</tr>
<tr>
<td>Never (N = 2033)</td>
<td>Past (N = 413) (n%, %)</td>
</tr>
<tr>
<td>Never use</td>
<td>1983 (78.0) 361 (14.2) 197 (7.8) 2319 (91.2) 162 (6.4) 62 (2.4) 2163 (85.0) 274 (10.8) 108 (4.2) 1903 (74.7) 431 (16.9) 215 (8.4)</td>
</tr>
<tr>
<td>Ever use</td>
<td>138 (47.4) 102 (33.1) 51 (17.5) 229 (78.4) 47 (16.1) 16 (5.5) 182 (62.3) 80 (27.4) 30 (10.3) 120 (41.0) 116 (39.6) 57 (19.3)</td>
</tr>
<tr>
<td>Hookah</td>
<td>1804 (82.7) 252 (11.5) 126 (5.8) 2040 (93.4) 104 (4.8) 39 (1.8) 1937 (88.6) 184 (8.4) 64 (2.9) 1746 (79.8) 305 (13.9) 137 (6.3)</td>
</tr>
<tr>
<td>Any tobacco product</td>
<td>229 (48.1) 161 (33.8) 86 (18.1) 365 (76.8) 35 (7.4) 29 (6.1) 300 (62.8) 128 (26.7) 51 (10.6) 201 (41.9) 185 (38.5) 94 (19.6)</td>
</tr>
<tr>
<td>0</td>
<td>1804 (82.7) 252 (11.5) 126 (5.8) 2040 (93.4) 104 (4.8) 39 (1.8) 1937 (88.6) 184 (8.4) 64 (2.9) 1746 (79.8) 305 (13.9) 137 (6.3)</td>
</tr>
<tr>
<td>1</td>
<td>187 (32.2) 110 (50.7) 61 (17.0) 285 (78.6) 60 (16.7) 17 (4.7) 239 (66.4) 85 (23.8) 36 (10.0) 165 (45.7) 129 (35.7) 67 (18.6)</td>
</tr>
<tr>
<td>≥2</td>
<td>42 (35.8) 51 (43.2) 25 (21.2) 85 (70.3) 23 (19.5) 12 (10.2) 61 (51.3) 43 (36.1) 15 (12.6) 36 (30.3) 56 (47.1) 27 (22.7)</td>
</tr>
</tbody>
</table>

Past use includes any noncurrent use of the respective product during the past 24 months; current use includes any use of the respective product during the past 30 days.

a Includes combustible cigarettes, e-cigarettes, and hookah.

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### Table 2: Prevalence of Baseline Tobacco Product Use Status and Follow-up Marijuana Product Use

<table>
<thead>
<tr>
<th>Baseline Use of Tobacco Products</th>
<th>Marijuana Product Use at 24-Mo Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combustible cigarettes</td>
<td>Marijuana Vaping</td>
</tr>
<tr>
<td>Never (N = 2033)</td>
<td>Past (N = 413) (n%, %)</td>
</tr>
<tr>
<td>Never use</td>
<td>1937 (88.6) 361 (14.2) 197 (7.8) 2319 (91.2) 162 (6.4) 62 (2.4) 2163 (85.0) 274 (10.8) 108 (4.2) 1903 (74.7) 431 (16.9) 215 (8.4)</td>
</tr>
<tr>
<td>Ever use</td>
<td>138 (47.4) 102 (33.1) 51 (17.5) 229 (78.4) 47 (16.1) 16 (5.5) 182 (62.3) 80 (27.4) 30 (10.3) 120 (41.0) 116 (39.6) 57 (19.3)</td>
</tr>
<tr>
<td>Hookah</td>
<td>1804 (82.7) 252 (11.5) 126 (5.8) 2040 (93.4) 104 (4.8) 39 (1.8) 1937 (88.6) 184 (8.4) 64 (2.9) 1746 (79.8) 305 (13.9) 137 (6.3)</td>
</tr>
<tr>
<td>Any tobacco product</td>
<td>229 (48.1) 161 (33.8) 86 (18.1) 365 (76.8) 35 (7.4) 29 (6.1) 300 (62.8) 128 (26.7) 51 (10.6) 201 (41.9) 185 (38.5) 94 (19.6)</td>
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<tr>
<td>0</td>
<td>1804 (82.7) 252 (11.5) 126 (5.8) 2040 (93.4) 104 (4.8) 39 (1.8) 1937 (88.6) 184 (8.4) 64 (2.9) 1746 (79.8) 305 (13.9) 137 (6.3)</td>
</tr>
<tr>
<td>1</td>
<td>187 (32.2) 110 (50.7) 61 (17.0) 285 (78.6) 60 (16.7) 17 (4.7) 239 (66.4) 85 (23.8) 36 (10.0) 165 (45.7) 129 (35.7) 67 (18.6)</td>
</tr>
<tr>
<td>≥2</td>
<td>42 (35.8) 51 (43.2) 25 (21.2) 85 (70.3) 23 (19.5) 12 (10.2) 61 (51.3) 43 (36.1) 15 (12.6) 36 (30.3) 56 (47.1) 27 (22.7)</td>
</tr>
</tbody>
</table>

Past use includes any noncurrent use of the respective product during the past 24 months; current use includes any use of the respective product during the past 30 days.

a Includes combustible cigarettes, e-cigarettes, and hookah.

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### Table 3: Associations Between Baseline Tobacco Ever Use and Marijuana Use at Follow-up in Baseline Never-Marijuana Users

Among never-marijuana users at baseline, 231 (8.7%) reported current use of at least 1 marijuana product at the 24-month follow-up, whereas 490 (18.4%) reported having used at least 1 product in the past 24 months leading up to the follow-up.

Table 3 shows the results of models that were unadjusted and adjusted for covariates. Here, we summarize the results of the adjusted models. Among baseline never-marijuana users, baseline ever (versus never) use of e-cigarettes was associated with the initiation of marijuana use (39.6% vs 15.7%; OR 3.63; 95% CI 2.69–4.90) and current marijuana use (19.5% vs 7.2%; OR 3.67; 95% CI 2.51–5.36) at the 24-month follow-up. Among never-marijuana users at baseline, 231 (8.7%) reported current use of at least 1 marijuana product at the 24-month follow-up, whereas 490 (18.4%) reported having used at least 1 product in the past 24 months leading up to the follow-up. Baseline ever use of e-cigarettes (OR 3.63; 95% CI 2.69–4.90) and current use of e-cigarettes (OR 3.67; 95% CI 2.51–5.36) at the 24-month follow-up was associated with the initiation of marijuana use (39.6% vs 15.7%; OR 3.63; 95% CI 2.69–4.90) and current marijuana use (19.5% vs 7.2%; OR 3.67; 95% CI 2.51–5.36) at the 24-month follow-up.
TABLE 3 Association of Baseline Multiple Tobacco Product Use and Covariates With Multiple Marijuana Product Outcomes at 24-Month Follow-up

<table>
<thead>
<tr>
<th>Outcome at 24-Mo Follow-up</th>
<th>Baseline Regressors, Ever Use</th>
<th>Current Versus Never, OR (95% CI)</th>
<th>Past Versus Never, OR (95% CI)</th>
<th>Current Versus Never, OR (95% CI)</th>
<th>Past Versus Never, OR (95% CI)</th>
<th>Current Versus Never, OR (95% CI)</th>
<th>Past Versus Never, OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unadjusted modelsa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combustible cigarettes</td>
<td>2.92 (1.61–5.32)**</td>
<td>5.73 (3.92–8.59)**</td>
<td>2.48 (1.04–5.92)**</td>
<td>4.11 (2.56–6.62)**</td>
<td>1.82 (0.92–3.62)**</td>
<td>4.07 (2.08–6.19)**</td>
<td>3.10 (1.71–5.60)**</td>
</tr>
<tr>
<td>Hookah</td>
<td>4.54 (2.39–8.62)**</td>
<td>5.46 (3.29–9.47)**</td>
<td>1.29 (0.70–2.37)**</td>
<td>2.69 (1.28–5.69)**</td>
<td>5.08 (3.56–9.11)**</td>
<td>4.68 (3.31–6.60)**</td>
<td>5.98 (3.97–8.74)**</td>
</tr>
<tr>
<td>Adjusted modelsb</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combustible cigarettes</td>
<td>1.90 (1.01–3.57)**</td>
<td>4.16 (2.07–8.41)**</td>
<td>1.54 (0.82–2.87)**</td>
<td>2.90 (1.75–4.79)**</td>
<td>1.76 (0.98–3.14)**</td>
<td>2.77 (1.77–4.32)**</td>
<td>1.97 (1.05–3.68)**</td>
</tr>
<tr>
<td>Any product</td>
<td>3.79 (2.73–5.27)**</td>
<td>3.81 (2.95–4.92)**</td>
<td>2.90 (1.70–4.93)**</td>
<td>3.33 (2.40–4.52)**</td>
<td>3.59 (2.36–5.43)**</td>
<td>3.26 (2.48–5.42)**</td>
<td>4.11 (3.05–5.61)**</td>
</tr>
<tr>
<td>No. products</td>
<td>2.55 (2.01–3.24)**</td>
<td>2.80 (2.30–3.40)**</td>
<td>1.94 (1.38–2.71)**</td>
<td>2.11 (1.70–2.63)**</td>
<td>2.19 (1.86–2.89)**</td>
<td>2.31 (1.90–2.80)**</td>
<td>2.77 (2.18–3.51)**</td>
</tr>
<tr>
<td>Combined adjusted modelsb</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combustible cigarettes</td>
<td>1.39 (0.72–2.68)</td>
<td>3.16 (2.01–4.98)**</td>
<td>1.13 (0.44–2.92)</td>
<td>2.22 (1.31–3.78)**</td>
<td>0.74 (0.31–1.74)</td>
<td>2.06 (1.29–3.28)**</td>
<td>1.43 (0.75–2.74)</td>
</tr>
<tr>
<td>E-cigarettes</td>
<td>2.41 (1.60–3.65)**</td>
<td>2.66 (1.93–5.58)**</td>
<td>1.30 (0.65–2.58)</td>
<td>1.81 (1.21–2.72)**</td>
<td>2.22 (1.33–3.71)**</td>
<td>2.20 (1.57–3.08)**</td>
<td>2.87 (1.91–3.50)**</td>
</tr>
<tr>
<td>Hookah</td>
<td>3.04 (1.94–4.76)**</td>
<td>2.38 (1.82–3.49)**</td>
<td>3.47 (1.79–6.79)**</td>
<td>2.25 (1.44–3.53)**</td>
<td>3.19 (1.88–5.41)**</td>
<td>2.37 (1.61–3.50)**</td>
<td>3.07 (1.97–4.80)**</td>
</tr>
</tbody>
</table>

a Unadjusted models include only the respective baseline tobacco product variable as the sole regressor.

b Adjusted models include the respective baseline tobacoo product variable, age, sex, race and/or ethnicity, parental education, family history of combustible cigarette and drug use, peer combustible cigarette use and marijuana use, TCI Impulsivity subscale, and CESD as simultaneous regressors. Combined adjusted models include all baseline tobacco products as simultaneous predictors and all covariate regressors.

*P < .05; **P < .01; ***P < .001.
the same models, significant effects were observed for e-cigarettes and hookah on current (versus never) marijuana product use, whereas combustible cigarettes did not.

**Associations Between Baseline Ever- Tobacco Use and Dual Use of Tobacco and Marijuana at Follow-up**

In the sample of never-marijuana users, adolescents who currently (versus never) used 1 of the 3 tobacco products (either e-cigarettes, hookah, or combustible cigarettes) at baseline were more likely to report current use of 1 of these tobacco products 24 months later (9.0% vs 3.6%; OR 2.38; 95% CI 1.58–3.58), current use of a marijuana product 24 months later (11.7% vs 3.3%; OR 3.23; 95% CI 2.18–4.79), and current dual use of 1 of these tobacco products and marijuana (7.9% vs 3.0%; OR 2.28; 95% CI 1.47–3.55; Table 4).

**DISCUSSION**

In the current study, we offer new evidence for a prospective relationship between adolescent e-cigarette and hookah use and the risk of initiating and currently using marijuana. E-cigarette and hookah use at age 14 years was associated with a 3.6- to fourfold increase in the odds of initiating and currently using marijuana 2 years later. Similar to combustible cigarette smoking, the use of e-cigarettes or hookah in early adolescence more than doubled the odds of currently using both tobacco and marijuana by midadolescence. These findings suggest that newer forms of tobacco likely increase adolescent vulnerability to marijuana use and dual use of marijuana and tobacco even in the context of other factors that are also correlated with marijuana use. Associations between the use of these tobacco products with subsequent marijuana use could reflect shared genetic liability to use both tobacco and marijuana as well as environmental features that make co-use more likely.1

An environment characterized by peer use, easier access, and shared perceptions of reduced risk increase the likelihood that e-cigarettes, hookah, and (ultimately) marijuana will be used.30–32 Even after adjusting for many of these shared risk factors for tobacco and marijuana use, the models remained robust, which increases our confidence that the observed associations were not attributable to another variable.

Indeed, the use of e-cigarettes and hookah may foster adolescent marijuana use. Nicotine primes the brain’s reward system by enhancing the level of pleasure experienced from subsequent drug exposures, such as to marijuana.33 Adolescents who initiate marijuana with (versus without) previous nicotine exposure may experience more pleasure from their initial marijuana use experience and progress more rapidly to regular marijuana use.43 Research reveals that a bout of hookah smoking can yield 1.7 times more nicotine than that of a combustible cigarette.24 As such, it is not surprising that the association between hookah smoking and subsequent use of all forms of marijuana use are the strongest. We did not measure whether adolescents had used electronic liquid (e-liquid) without nicotine or tobacco-free (herbal) forms of hookah at baseline, and therefore, we cannot confirm the role of nicotine in the current results. Yet, 63% of current adolescent e-cigarette users at follow-up reported using e-liquid with nicotine, and teenagers who report using e-liquids without nicotine may also be inadvertently exposed because nicotine has been detected in >90% of e-liquids sampled, including those that are labeled as nicotine free.35,36

Additionally, airway adaptations that occur as part of hookah smoking and e-cigarette vaping may facilitate marijuana smoking and vaping by reducing sensitivity to the irritation caused by the inhalation of marijuana products. Repeated inhalation of hot hookah smoke and habituation to the “throat hit” associated with propylene glycol in e-liquid may render the transition to smoking or vaping marijuana more pleasant and thus likely to be repeated. It is important to point out that hookah is the only tobacco product of the 3 studied that is characterized by flavor and combustion. Perhaps these combined features, in addition to a shared form of administration (eg, water pipe), foster the use of both hookah and marijuana.

The associations between e-cigarette and hookah use and subsequent marijuana use are stronger than those for combustible cigarettes. E-cigarette and hookah use is more prevalent than combustible cigarette smoking among adolescents, yet e-cigarettes and hookah are far less regulated10,37 Federal regulations do not currently restrict youth-targeted advertising and promotion or sales of youth-friendly flavors of

**TABLE 4 Association of Baseline Tobacco Product Use and Dual Product Use at 24-Month Follow-up**

<table>
<thead>
<tr>
<th>Baseline Regressor; Ever Any Tobacco Product Use</th>
<th>Current Product Use at 24 Mo Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tobacco Product&lt;sup&gt;a&lt;/sup&gt; Versus None, OR (95% CI)</td>
<td>Marijuana Product&lt;sup&gt;b&lt;/sup&gt; Versus None, OR (95% CI)</td>
</tr>
<tr>
<td>Unadjusted model</td>
<td>3.22 (2.18–4.75)&lt;sup&gt;***&lt;/sup&gt;</td>
</tr>
<tr>
<td>Adjusted model</td>
<td>2.38 (1.58–3.59)&lt;sup&gt;***&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Current use includes any use of the respective product during the past 30 days.

<sup>a</sup> Current use of any combustible cigarettes, e-cigarettes, or hookah.
<sup>b</sup> Current use of any combustible marijuana, vaping marijuana or marijuana edibles.
<sup>c</sup> Current use of any combustible cigarettes, e-cigarettes, or hookah and any combustible marijuana, vaping marijuana or marijuana edibles.

<sup>**P < .001.  </sup>
e-cigarette and hookah products. Likewise, access does not currently appear to be a significant barrier to use. For example, of the adolescents who reported smoking hookah, 27% smoked it at a friend’s house, 8% smoked at a hookah bar or café, 8% smoked at home, 6% smoked somewhere else, 8% smoked at multiple locations, and 43% chose not to indicate where they smoke hookah. Recent trends in marijuana policy across numerous states in the United States are moving toward increasing legalization; such trends have been associated with a higher prevalence of use of both marijuana and tobacco. With the data from the current study, we raise questions regarding the impact of less restrictive policies on the use and co-use of newer tobacco products and marijuana in the adolescent population. These data are used to support strict policies to prevent tobacco product and marijuana product sales to minors. Hookah smoking has many of the same health risks as combustible cigarette smoking. Although some e-cigarette advocates may not be alarmed by youth trying e-cigarettes, concerns should be heightened by the finding that e-cigarette use is associated with marijuana use as well as dual use.

Dual use of tobacco and marijuana is particularly troubling because it increases the likelihood of an adolescent becoming dependent on both nicotine and cannabis. Adolescents are likely to continue to use both because of greater withdrawal symptoms and declines in cognitive functioning during abstinence than adolescents who only use tobacco. As such, interventions and regulations to prevent adolescent e-cigarette, hookah, and marijuana use are critical.

The study has several strengths, including having a demographically diverse sample that was measured during a developmentally vulnerable period for substance use, using repeated measures of tobacco and marijuana initiation and current use, excluding adolescents who had ever used marijuana at baseline to clarify temporal precedence, and having high participation and retention rates.

A limitation of this study is that the frequency of marijuana use was not measured, only use in the past 30 days. As such, we are not able to determine whether e-cigarette or hookah use is associated with a specific level of marijuana use beyond current use. Likewise, specific characteristics of e-cigarettes and hookah (eg, flavoring) were not assessed; thus, the role of these characteristics in marijuana uptake cannot be determined.

The sample was drawn from a specific location, which may lessen generalizability. However, given that California has decriminalized marijuana for recreational use, the present sample may offer a snapshot of the likely associations between novel tobacco products and marijuana use in a state where tobacco regulations are more restrictive and marijuana use is more normalized. It is important to note that the prevalence of e-cigarette and hookah use in the current study are comparable to those rates identified in national studies. Lastly, this is an observational study and the first to examine these associations. Inferences regarding whether the identified associations are causal cannot be made but should be the subject of future research. It will also be valuable to identify mechanisms that drive marijuana use among adolescents who have used e-cigarettes and hookah.

CONCLUSIONS

Adolescents who used e-cigarettes or hookah at baseline compared with those who did not were more likely to report initiation and current use of marijuana as well as dual use of tobacco and marijuana. The association between tobacco use and subsequent marijuana use across adolescence extends to multiple tobacco products.

ABBREVIATIONS

CESD: Center for Epidemiologic Studies Depression Scale
CI: confidence interval
e-cigarette: electronic cigarette
e-liquid: electronic liquid
OR: odds ratio
TCI: Temperament and Character Inventory

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