The Association Between Smoking and Electronic Cigarette Use in a Cohort of Young People

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A longitudinal survey of 1,152 11- to 18-year-olds was conducted with baseline in April 2016 and follow-up between August and October 2016. Logistic regression models and causal mediation analyses assessed whether (1) ever e-cigarette use and escalation were associated with smoking initiation (ever smoking at follow-up) among baseline never smokers (n = 923), and (2) ever smoking and escalation were associated with e-cigarette initiation (ever e-cigarette use at follow-up) among baseline never e-cigarette users (n = 1,020).

Results: At baseline, 19.8% were ever smokers and 11.4% were ever e-cigarette users. Respondents who were ever e-cigarette users (vs. never users, 53% vs. 8%, odds ratio [OR] = 11.89, 95% confidence interval [CI] = 3.56–39.72) and escalated their e-cigarette use (vs. did not, 41% vs. 8%, OR = 7.89, 95% CI = 3.06–20.38) were more likely to initiate smoking. Respondents who were ever smokers (vs. never smokers, 32% vs. 4%, OR = 3.54, 95% CI = 1.68–7.45) and escalated their smoking (vs. did not, 34% vs. 6%, OR = 5.79, 95% CI = 2.55–13.15) were more likely to initiate e-cigarette use. There was a direct effect of ever e-cigarette use on smoking initiation (OR = 1.34, 95% CI = 1.05–1.72), and ever smoking on e-cigarette initiation (OR = 1.08, 95% CI = 1.01–1.17); e-cigarette initiation, and additionally finds that ever smoking is associated with e-cigarette initiation, among young people.
Conclusions: Among young people in Great Britain, ever e-cigarette use is associated with smoking initiation, and ever smoking is associated with e-cigarette initiation.

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At follow-up, respondents were further classified as having escalated smoking (increased their smoking between baseline and follow-up, e.g., escalating from never smoking to trying smoking, from smoking sometimes to smoking between one and six cigarettes a week) or not escalated smoking. Respondents were classified using the same procedure for e-cigarette use. Respondents who had never heard of e-cigarettes (n = 178), and those who responded with "Prefer not to say" or "Don't know" to the smoking or e-cigarette question at either baseline or follow-up (n = 65) were excluded from all analyses. Full item wording and response options are available in Table A1 (Supplementary Data).

Covariates (assessed at baseline only). Age (11–13, 14–15, 16–18), gender (male, female), school performance (1–4, below average to excellent), problem behavior (2–8, 8 = greater problem behavior), monthly alcohol use (yes, no), smoking susceptibility (susceptible, not susceptible) [26], e-cigarette susceptibility (susceptible, not susceptible—to mirror smoking susceptibility [26]), some friends smoke (yes, no, not applicable/don’t know), some friends use e-cigarettes (yes, no, not applicable/don’t know), at least one parent smokes (yes, no), at least one parent uses e-cigarettes (yes, no), sibling(s) smoke (yes, no, not applicable/don’t know), sibling(s) use e-cigarettes (yes, no, not applicable/don’t know), public approval of smoking (yes, no), and public approval of e-cigarettes (yes, no) [27]. For school performance, problem behavior, monthly alcohol use, and smoking and e-cigarette susceptibility, “Don’t know” and “Prefer not to say” responses were excluded from all analyses. Covariates specific to smoking were selected based on the previous literature [12,15,18,26–28] and friend, parental, and sibling e-cigarette use and public approval of e-cigarettes were also included to mirror the similar smoking measures and to explore potential shared risk factors for each product. Full item wording, response options, and further details on coding for all covariates are available in Table A1 (Supplementary Data).

Statistical analysis

We used unadjusted logistic regressions to compare respondents lost to follow-up with those retained and included in the study sample. We then used chi-square tests to compare smoking and e-cigarette status at baseline and follow-up. We used unadjusted and adjusted logistic regressions to explore the associations between (1) ever e-cigarette use at baseline and e-cigarette escalation between baseline and follow-up with smoking initiation at follow-up among baseline never smokers (n = 923), and (2) ever smoking at baseline and smoking escalation between baseline and follow-up with e-cigarette initiation at follow-up among baseline never e-cigarette users (n = 1,020). In adjusted models, we adjusted for all covariates described in the Measures section.

To decompose the causal effect of e-cigarette use on smoking initiation, and smoking on e-cigarette initiation, we used causal mediation analyses using the parametric g-computation procedure [25]. Mediation analyses go beyond standard regression
models, which can estimate the associations between use of both products, by disentangling different pathways that could explain the effect of an exposure on an outcome. Furthermore, when a potential mediator is treated as confounder in standard regression models, spurious associations may arise. The most commonly used mediation analysis in epidemiology is based on the Baron and Kenny approach [29], in which the total effect of an exposure on an outcome, the effect of the exposure explained by a given set of mediators (indirect effect), and the effect of the exposure unexplained by those same mediators (direct effect) can be defined. This approach has four main problems as it (1) assumes no unmeasured confounding between mediator and outcome, (2) assumes no interactions between exposure and mediator on outcome, (3) does not extend to nonlinear models, and (4) assumes correctly specified models.

Causal mediation analysis has arisen from the causal inference literature [30] and addressed problems of the Baron and Kenny approach [29] under the potential outcomes framework, first by defining (using potential outcomes) precisely what is meant by direct and indirect effects, second by giving clear assumptions under which they can be identified, and third by generalizing the statistical methods available for carrying out such analyses to allow for nonlinearities, interactions, discrete outcomes, and semiparametric estimation [31]. We therefore use the parametric g-computation procedure under this framework as it can quantify reliable direct and indirect causal effects for binary variables, and produces narrow confidence intervals to allow for stronger conclusions to be made regarding observed associations [25,32]. The g-computation procedure is discussed in detail elsewhere [25,31,32], but primarily relies on the parametric modeling assumptions shared with logistic regression and, to infer causality, assumes no unmeasured confounding. It has been applied to survey data previously [33].

To assess the causal influence of e-cigarette use on smoking initiation, we specified a direct effect from ever e-cigarette use at baseline to smoking initiation at follow-up and an indirect effect acting through e-cigarette escalation between baseline and follow-up (mediator). We used the same approach to assess the causal influence of ever smoking on smoking initiation at follow-up compared with those who did not (Table 1), and this increased to 301 (26.0%) at follow-up ($\chi^2 = 834.32, p < .001$). Of the 229 baseline ever smokers, 111 (48.5%) were also ever e-cigarette users; of the 923 baseline never smokers, 21 (2.3%) were ever e-cigarette users. At baseline, 132 respondents (11.5%) had ever used an e-cigarette (Table 1), and increased to 204 (17.6%) at follow-up ($\chi^2 = 761.74, p < .001$). Of the 132 baseline ever e-cigarette users, 111 (84.0%) were also ever smokers; of the 1,020 baseline never e-cigarette users, 118 (11.6%) were ever smokers. At baseline, only 56 (4.9%) respondents smoked monthly or more and 24 (2.1%) used an e-cigarette monthly or more.

Compared with baseline never e-cigarette users, ever e-cigarette users were more likely to initiate smoking at follow-up (Table 2). Furthermore, respondents who escalated e-cigarette use between baseline and follow-up were also more likely to initiate smoking at follow-up compared with those who did not (Table 2).

Compared with baseline never smokers, ever smokers were more likely to initiate e-cigarette use at follow-up (Table 3). Furthermore, respondents who escalated smoking between baseline and follow-up were also more likely to initiate e-cigarette use at follow-up compared with those who did not (Table 3).

Results

Table 1 shows the characteristics of the study sample at baseline ($n = 1,152$) compared with respondents lost to follow-up and who would have otherwise been included (because of not having heard of e-cigarettes or selecting “don’t know” or “prefer not to say” on key variables and covariates) ($n = 1,225$). Respondents were more likely to be lost to follow-up if they had ever smoked and ever used an e-cigarette, and also differed on all covariates included in the study except smoking susceptibility and having at least one parent who uses e-cigarettes.

At baseline, 229 respondents (19.9%) had ever smoked (Table 1), and this increased to 301 (26.0%) at follow-up ($\chi^2 = 834.32, p < .001$). Of the 229 baseline ever smokers, 111 (48.5%) were also ever e-cigarette users; of the 923 baseline never smokers, 21 (2.3%) were ever e-cigarette users. At baseline, 132 respondents (11.5%) had ever used an e-cigarette (Table 1), and increased to 204 (17.6%) at follow-up ($\chi^2 = 761.74, p < .001$). Of the 132 baseline ever e-cigarette users, 111 (84.0%) were also ever smokers; of the 1,020 baseline never e-cigarette users, 118 (11.6%) were ever smokers. At baseline, only 56 (4.9%) respondents smoked monthly or more and 24 (2.1%) used an e-cigarette monthly or more.

Compared with baseline never e-cigarette users, ever e-cigarette users were more likely to initiate smoking at follow-up (Table 2). Furthermore, respondents who escalated e-cigarette use between baseline and follow-up were also more likely to initiate smoking at follow-up compared with those who did not (Table 2).

Compared with baseline never smokers, ever smokers were more likely to initiate e-cigarette use at follow-up (Table 3). Furthermore, respondents who escalated smoking between baseline and follow-up were also more likely to initiate e-cigarette use at follow-up compared with those who did not (Table 3).

Having some friends who use an e-cigarette reduced the likelihood of smoking initiation (Table 2) but increased the likelihood of e-cigarette initiation (Table 3). Being older, susceptible to smoking, and having at least one parent who smokes were associated with an increased likelihood of smoking initiation (Table 2). Monthly alcohol use and no perceived public approval of smoking were associated with an increased likelihood of e-cigarette initiation (Table 3).
and e-cigarette initiation. We also found that escalation of each e-cigarette use and smoking initiation, and between ever smoking we found evidence for a prospective association between ever smoking and e-cigarette use and smoking initiation, and between ever smoking and e-cigarette initiation. In the logistic regression analyses, to assess the relative contribution of these associations using a causal inference approach. In the logistic regression analyses, we found evidence for a prospective association between ever e-cigarette use and smoking initiation, and between ever smoking and e-cigarette initiation. We also found that escalation of each product (e-cigarettes and smoking) between baseline and follow-up was associated with initiation of the alternative product. The causal mediation analyses confirmed the direct effect of baseline ever e-cigarette use on smoking initiation, and baseline ever smoking on e-cigarette initiation, but found that e-cigarette and smoking escalation, respectively, did not mediate these effects.

This study provides insight into the impact of e-cigarette use on smoking and vice versa in young people; however, the findings must be considered in the light of some limitations. Attrition was high and respondents lost to follow-up differed substantially from those retained, potentially reducing generalizability to ever smokers, ever e-cigarette users, males, older respondents, and those with poorer school performance and greater problem behavior.

Although this study controlled for a variety of factors previously associated with smoking and e-cigarette use to enhance approximation of the models, there are still several factors that were not included that may contribute to the observed association between these products [28]. Examples may include curiosity, sensation seeking, liking, or disliking the effects of smoking/e-cigarettes, expectancies of smoking/e-cigarettes, mental ill health, and use of other drugs [28]. Furthermore, there are likely to be contributing factors that cannot be easily measured in surveys such as biological or genetic vulnerabilities, although drug use and parent's smoking and e-cigarette use may act as an indicator of these. Larger sample sizes are required to enable this substantial number of covariates to be assessed and meaningfully interpreted.

### Table 1

<table>
<thead>
<tr>
<th>Study sample (n = 1,152)</th>
<th>Lost to follow-up and excluded (n = 1,225)</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ever smoked</td>
<td>229 (19.88)</td>
<td>382 (31.18)</td>
</tr>
<tr>
<td>Ever used e-cigarettes</td>
<td>132 (11.46)</td>
<td>297 (24.24)</td>
</tr>
<tr>
<td>Female</td>
<td>620 (53.82)</td>
<td>564 (46.04)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11–13</td>
<td>438 (38.02)</td>
<td>375 (30.61)</td>
</tr>
<tr>
<td>14–15</td>
<td>338 (29.34)</td>
<td>263 (21.47)</td>
</tr>
<tr>
<td>16–18</td>
<td>376 (32.64)</td>
<td>587 (47.92)</td>
</tr>
<tr>
<td>School performance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1–4, 4 = excellent), mean (SD)</td>
<td>3.05 (.8)</td>
<td>2.97 (.8)</td>
</tr>
<tr>
<td>Problem behavior</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2–8, 8 = high), mean (SD)</td>
<td>2.93 (1.2)</td>
<td>3.30 (1.4)</td>
</tr>
<tr>
<td>Monthly alcohol use</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>269 (23.35)</td>
<td>407 (33.22)</td>
</tr>
<tr>
<td>Susceptible to smoking</td>
<td>146 (12.67)</td>
<td>151 (12.33)</td>
</tr>
<tr>
<td>Susceptible to using e-cigarettes</td>
<td>264 (22.92)</td>
<td>330 (26.94)</td>
</tr>
<tr>
<td>Some friends smoke</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>371 (32.2)</td>
<td>279 (22.78)</td>
</tr>
<tr>
<td>Yes</td>
<td>727 (63.11)</td>
<td>894 (72.98)</td>
</tr>
<tr>
<td>DK/NA</td>
<td>54 (4.69)</td>
<td>52 (4.24)</td>
</tr>
<tr>
<td>Some friends use e-cigarettes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>684 (59.38)</td>
<td>526 (42.94)</td>
</tr>
<tr>
<td>Yes</td>
<td>399 (34.64)</td>
<td>620 (50.61)</td>
</tr>
<tr>
<td>DK/NA</td>
<td>69 (5.99)</td>
<td>79 (6.45)</td>
</tr>
<tr>
<td>At least one parent smokes</td>
<td>343 (29.77)</td>
<td>413 (33.71)</td>
</tr>
<tr>
<td>At least one parent uses e-cigarettes</td>
<td>182 (15.8)</td>
<td>221 (18.04)</td>
</tr>
<tr>
<td>Sibling(s) smokes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>918 (79.69)</td>
<td>935 (76.33)</td>
</tr>
<tr>
<td>Yes</td>
<td>127 (11.02)</td>
<td>191 (15.59)</td>
</tr>
<tr>
<td>NA/DK</td>
<td>107 (9.20)</td>
<td>99 (8.08)</td>
</tr>
<tr>
<td>Sibling(s) use e-cigarettes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>992 (86.11)</td>
<td>1016 (82.94)</td>
</tr>
<tr>
<td>Yes</td>
<td>54 (4.69)</td>
<td>119 (9.71)</td>
</tr>
<tr>
<td>NA/DK</td>
<td>106 (9.20)</td>
<td>90 (7.35)</td>
</tr>
<tr>
<td>Public approve of smoking</td>
<td>33 (2.86)</td>
<td>62 (5.06)</td>
</tr>
<tr>
<td>Public approve of e-cigarettes</td>
<td>43 (3.73)</td>
<td>90 (7.35)</td>
</tr>
</tbody>
</table>

All data are unweighted. Significant associations (p < 0.05) are highlighted in **bold**.

N (%) of the samples are reported unless otherwise stated.

In the causal mediation analysis (Figure 2, model A), baseline ever e-cigarette use had a direct causal effect on smoking initiation at follow-up (odds ratio [OR] = 1.34, 95% confidence interval [CI] = 1.05–1.72, p = .018), and there was a significant total causal effect of the model (OR = 1.35, 95% CI = 1.04–1.74, p = .022). However, there was no indirect effect of baseline ever e-cigarette use on smoking initiation at follow-up mediated by e-cigarette escalation between baseline and follow-up (OR = 1.00, 95% CI = 0.91–1.11, p = .983).

In the causal mediation analysis (Figure 2, model B), baseline ever smoking had a direct causal effect on e-cigarette initiation at follow-up (OR = 1.08, 95% CI = 1.01–1.17, p = .034), and there was a significant total causal effect of the model (OR = 1.11, 95% CI = 1.03–1.20, p = .006). However, there was no indirect effect of baseline ever smoking on e-cigarette initiation at follow-up mediated by smoking escalation between baseline and follow-up (OR = 1.03, 95% CI = .99–1.06, p = .106).

### Discussion

This study was the first to explore the longitudinal association between e-cigarette use and smoking initiation, and smoking and e-cigarette initiation among young people in Great Britain, and to assess the relative contribution of these associations using a causal inference approach. In the logistic regression analyses, we found evidence for a prospective association between ever e-cigarette use and smoking initiation, and between ever smoking and e-cigarette initiation. We also found that escalation of each product (e-cigarettes and smoking) between baseline and follow-up was associated with initiation of the alternative product. The causal mediation analyses confirmed the direct effect of baseline ever e-cigarette use on smoking initiation, and baseline ever smoking on e-cigarette initiation, but found that e-cigarette and smoking escalation, respectively, did not mediate these effects.

This study provides insight into the impact of e-cigarette use on smoking and vice versa in young people; however, the findings must be considered in the light of some limitations. Attrition was high and respondents lost to follow-up differed substantially from those retained, potentially reducing generalizability to ever smokers, ever e-cigarette users, males, older respondents, and those with poorer school performance and greater problem behavior.

Although this study controlled for a variety of factors previously associated with smoking and e-cigarette use to enhance approximation of the models, there are still several factors that were not included that may contribute to the observed association between these products [28]. Examples may include curiosity, sensation seeking, liking, or disliking the effects of smoking/e-cigarettes, expectancies of smoking/e-cigarettes, mental ill health, and use of other drugs [28]. Furthermore, there are likely to be contributing factors that cannot be easily measured in surveys such as biological or genetic vulnerabilities, although drug use and parent’s smoking and e-cigarette use may act as an indicator of these. Larger sample sizes are required to enable this substantial number of covariates to be assessed and meaningfully interpreted.
Another important limitation is that this study uses the outcomes smoking initiation and e-cigarette initiation defined as progressing from never to ever use of each product. This is similar to some previous studies [12–16,21,24], yet the use of such broad measures has been criticized for providing limited evidence of progression to any significant smoking behavior [28,34]. However, because of low prevalence rates of monthly or more smoking (5%) and e-cigarette use (2%) in this study’s sample, options for refining the measures were limited. Therefore, although the present study found an association between ever smoking and ever e-cigarette use, these cannot be generalized to current or regular use, and it cannot be determined whether e-cigarette experimentation leads to regular smoking. Such questions are critical in this area of research. Surveys with multiple waves across several years with larger sample sizes are needed to enable higher numbers of ever and current smokers and e-cigarette users, and further dissect the association between the two products.

### Table 2

<table>
<thead>
<tr>
<th>Baseline EC use</th>
<th>n (% initiated smoking)</th>
<th>Unadjusted OR (95% CI)</th>
<th>Adjusted model 1&lt;sup&gt;c&lt;/sup&gt; OR (95% CI)</th>
<th>Adjusted model 2&lt;sup&gt;b&lt;/sup&gt; OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>902 (8.2)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Ever</td>
<td>21 (52.6)</td>
<td>12.41 (4.53–33.99)</td>
<td>.001</td>
<td>10.57 (3.33–33.50)</td>
</tr>
<tr>
<td>Follow-up EC use</td>
<td></td>
<td>7.94 (3.75–16.82)</td>
<td>.001</td>
<td>4.02 (1.72–9.40)</td>
</tr>
<tr>
<td>No escalation</td>
<td>882 (8.1)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Escalation</td>
<td>41 (41.0)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>11–13</td>
<td>397 (4.4)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>14–15</td>
<td>270 (6.3)</td>
<td>1.45 (.71–2.97)</td>
<td>.312</td>
<td>1.22 (.54–2.73)</td>
</tr>
<tr>
<td>16–18</td>
<td>256 (16.1)</td>
<td>4.12 (2.19–7.76)</td>
<td>.001</td>
<td>4.02 (1.72–9.40)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Male</td>
<td>428 (10.8)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Female</td>
<td>495 (8.5)</td>
<td>.77 (.46–1.30)</td>
<td>.331</td>
<td>.90 (.48–1.68)</td>
</tr>
<tr>
<td>School perf. (1–4, 4 = excellent)&lt;sup&gt;x&lt;/sup&gt;</td>
<td>2.93 (9.9)</td>
<td>.76 (.53–1.18)</td>
<td>.124</td>
<td>.91 (.64–1.29)</td>
</tr>
<tr>
<td>Problem beh. (2–8, 8 = high)&lt;sup&gt;y&lt;/sup&gt;</td>
<td>3.05 (13.0)</td>
<td>1.31 (1.03–1.66)</td>
<td>.028</td>
<td>1.06 (0.82–1.37)</td>
</tr>
<tr>
<td>Monthly alcohol use</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>790 (7.8)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Yes</td>
<td>133 (18.1)</td>
<td>2.61 (1.42–4.80)</td>
<td>.002</td>
<td>1.64 (.82–3.30)</td>
</tr>
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<td>Smoking susceptibility</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>777 (7.9)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Yes</td>
<td>146 (19.8)</td>
<td>2.88 (1.57–5.29)</td>
<td>.001</td>
<td>2.38 (1.17–4.84)</td>
</tr>
<tr>
<td>Some friends smoke</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>355 (5.4)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Yes</td>
<td>515 (12.9)</td>
<td>2.60 (1.34–5.07)</td>
<td>.005</td>
<td>1.48 (.66–3.34)</td>
</tr>
<tr>
<td>NA/DK</td>
<td>53 (13.9)</td>
<td>.35 (.04–2.76)</td>
<td>.317</td>
<td>.30 (.04–2.43)</td>
</tr>
<tr>
<td>School perf. (1–4, 4 = excellent)&lt;sup&gt;x&lt;/sup&gt;</td>
<td>598 (8.6)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Problem beh. (2–8, 8 = high)&lt;sup&gt;y&lt;/sup&gt;</td>
<td>264 (11.0)</td>
<td>1.32 (.73–2.40)</td>
<td>.358</td>
<td>.47 (.24–.93)</td>
</tr>
<tr>
<td>Monthly alcohol use</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>676 (6.8)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Yes</td>
<td>247 (18.0)</td>
<td>2.99 (1.72–5.20)</td>
<td>.001</td>
<td>2.97 (1.62–5.44)</td>
</tr>
<tr>
<td>At least one parent smokes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>802 (8.4)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Yes</td>
<td>121 (18.8)</td>
<td>2.54 (1.35–4.76)</td>
<td>.004</td>
<td>1.47 (.70–3.07)</td>
</tr>
<tr>
<td>Sibling(s) smoke</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>761 (8.5)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Yes</td>
<td>71 (20.8)</td>
<td>2.83 (1.23–6.51)</td>
<td>.015</td>
<td>.75 (.30–1.84)</td>
</tr>
<tr>
<td>NA/DK</td>
<td>91 (10.4)</td>
<td>1.25 (.56–2.82)</td>
<td>.584</td>
<td>1.65 (.56–4.92)</td>
</tr>
<tr>
<td>Public approve of smoking</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>810 (9.3)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
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<tr>
<td>Yes</td>
<td>28 (24.3)</td>
<td>3.13 (1.09–9.01)</td>
<td>.034</td>
<td>2.16 (.54–8.58)</td>
</tr>
<tr>
<td>NA/DK</td>
<td>85 (9.3)</td>
<td>1.00 (.41–2.41)</td>
<td>.998</td>
<td>.72 (.20–2.53)</td>
</tr>
<tr>
<td>Public approve of ECs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>903 (9.5)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Yes</td>
<td>20 (20.5)</td>
<td>2.45 (.60–9.96)</td>
<td>.209</td>
<td>1.33 (.34–5.16)</td>
</tr>
<tr>
<td>At least one parent uses EC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>907 (9.7)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Yes</td>
<td>16 (9.8)</td>
<td>1.00 (.20–4.99)</td>
<td>.997</td>
<td>.39 (.07–2.05)</td>
</tr>
</tbody>
</table>

Adjusted model 1 constant OR = .02 (95% CI = .00–.11) p < .001. Adjusted model 2 constant OR = .02 (95% CI = .00–.10), p < .001. N and % illustrate the number and percentage of individuals who initiated smoking at follow-up. All n use unweighted data, % and analyses use weighted data. Significant associations (p < .05) are highlighted in **bold.**

<sup>a</sup> Adjusted model 1 is adjusted for all variables listed except follow-up EC use.
<sup>b</sup> Adjusted model 2 is adjusted for all variables listed.
<sup>c</sup> Mean(SD) reported, mean (SD) for never smoked at follow-up: school performance = 3.12 (0.8), problem behavior = 2.71 (1.0).
Despite the above limitations, this study has several strengths. It was the first to explicitly explore the association not only between e-cigarette use at baseline and smoking initiation at follow-up but additionally smoking at baseline and e-cigarette initiation at follow-up. Moreover, a novel statistical approach (causal mediation analysis [25]) was used to explore whether the association between baseline ever e-cigarette use and smoking initiation at follow-up was mediated by escalation of e-cigarette use between survey waves; the same procedure was also used to explore further the association between smoking and e-cigarette initiation. To our knowledge this has not been done previously. Finally, the sample was drawn from the general population in Great Britain using a quota sampling approach to enhance representativeness.

The rate of ever smoking in this study was 19.9% at baseline, but could be because of those lost at follow-up being more likely to smoke. The rate of ever e-cigarette use (11.5% at baseline) and all covariates, among baseline never e-cigarette users (n = 1,020).

<table>
<thead>
<tr>
<th>Baseline smoking</th>
<th>Unadjusted OR (95% CI)</th>
<th>p</th>
<th>Adjusted model 1* OR (95% CI)</th>
<th>p</th>
<th>Adjusted model 2† OR (95% CI)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>1.00</td>
<td></td>
<td>3.69 (1.88–7.23)</td>
<td>.001</td>
<td>3.54 (1.68–7.45)</td>
<td>.001</td>
</tr>
<tr>
<td>Ever</td>
<td>948 (5.36–16.76)</td>
<td>&lt;.001</td>
<td>2.60 (1.88–7.23)</td>
<td>&lt;.001</td>
<td>2.59 (1.68–7.45)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Follow-up smoking</td>
<td>88 (33.5)</td>
<td>1.00</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>No escalation</td>
<td>1.00</td>
<td></td>
<td>—</td>
<td>—</td>
<td>5.79 (2.55–13.15)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Escalation</td>
<td>8.00 (4.36–14.69)</td>
<td>&lt;.001</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Age</td>
<td>313 (12.5)</td>
<td>2.41 (1.29–4.51)</td>
<td>.006</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>11–13</td>
<td>413 (5.6)</td>
<td>1.00</td>
<td>—</td>
<td>—</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>14–15</td>
<td>294 (6.1)</td>
<td>1.11 (.54–2.27)</td>
<td>.779</td>
<td>.65 (2.9–14.3)</td>
<td>.285</td>
<td>.57 (.25–127)</td>
</tr>
<tr>
<td>16–18</td>
<td>313 (12.5)</td>
<td>2.41 (1.29–4.51)</td>
<td>.006</td>
<td>.69 (31–155)</td>
<td>.374</td>
<td>.48 (19–118)</td>
</tr>
<tr>
<td>Gender</td>
<td>468 (10.2)</td>
<td>1.00</td>
<td>—</td>
<td>—</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>552 (7.3)</td>
<td>.70 (.41–1.17)</td>
<td>.171</td>
<td>.77 (.41–1.43)</td>
<td>.404</td>
<td>.73 (.39–137)</td>
</tr>
<tr>
<td>School perf. (1–4 = excellent)c</td>
<td>2.67 (9.9)</td>
<td>2.57 (.42–.78)</td>
<td>&lt;.001</td>
<td>.81 (.58–114)</td>
<td>.226</td>
<td>.79 (.55–112)</td>
</tr>
<tr>
<td>Problem beh. (2–8 = high)d</td>
<td>3.51 (1.4)</td>
<td>1.62 (1.30–2.03)</td>
<td>&lt;.001</td>
<td>1.20 (.93–1.53)</td>
<td>.154</td>
<td>1.13 (.87–147)</td>
</tr>
<tr>
<td>Monthly alcohol use</td>
<td>824 (5.0)</td>
<td>1.00</td>
<td>—</td>
<td>—</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>EC susceptibility</td>
<td>756 (5.1)</td>
<td>1.00</td>
<td>—</td>
<td>—</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>264 (18.9)</td>
<td>4.39 (2.51–7.67)</td>
<td>&lt;.001</td>
<td>1.53 (.83–2.83)</td>
<td>.173</td>
<td>1.67 (.86–3.27)</td>
</tr>
<tr>
<td>Some friends smoke</td>
<td>196 (20.6)</td>
<td>4.93 (2.87–8.47)</td>
<td>&lt;.001</td>
<td>2.66 (127.5–61)</td>
<td>.010</td>
<td>2.40 (108–53)</td>
</tr>
<tr>
<td>No</td>
<td>196 (20.6)</td>
<td>4.93 (2.87–8.47)</td>
<td>&lt;.001</td>
<td>2.66 (127.5–61)</td>
<td>.010</td>
<td>2.40 (108–53)</td>
</tr>
<tr>
<td>NA/DK</td>
<td>54 (5.5)</td>
<td>2.34 (5.6–9.24)</td>
<td>.247</td>
<td>3.24 (60–1736)</td>
<td>.170</td>
<td>4.31 (88–2113)</td>
</tr>
<tr>
<td>At least one parent smokes</td>
<td>660 (5.7)</td>
<td>3.14 (1.81–5.45)</td>
<td>&lt;.001</td>
<td>2.69 (148–487)</td>
<td>.001</td>
<td>3.03 (163–64)</td>
</tr>
<tr>
<td>No</td>
<td>293 (15.9)</td>
<td>1.15 (.31–419)</td>
<td>.835</td>
<td>1.10 (.20–614)</td>
<td>.915</td>
<td>.78 (14–54)</td>
</tr>
<tr>
<td>At least one parent uses EC</td>
<td>733 (6.6)</td>
<td>2.47 (1.45–4.23)</td>
<td>.001</td>
<td>1.88 (.91–3.91)</td>
<td>.090</td>
<td>1.45 (.61–3.46)</td>
</tr>
<tr>
<td>No</td>
<td>287 (14.9)</td>
<td>2.47 (1.45–4.23)</td>
<td>.001</td>
<td>1.88 (.91–3.91)</td>
<td>.090</td>
<td>1.45 (.61–3.46)</td>
</tr>
<tr>
<td>Sibling(s) smoke</td>
<td>136 (17.3)</td>
<td>2.54 (1.38–4.67)</td>
<td>.003</td>
<td>2.34 (100–547)</td>
<td>.051</td>
<td>2.1 (.87–5.07)</td>
</tr>
<tr>
<td>No</td>
<td>884 (7.6)</td>
<td>1.00</td>
<td>—</td>
<td>—</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>2.54 (1.38–4.67)</td>
<td>.003</td>
<td>2.34 (100–547)</td>
<td>.051</td>
<td>2.1 (.87–5.07)</td>
<td>.097</td>
</tr>
<tr>
<td>NA/DK</td>
<td>94 (24.0)</td>
<td>3.94 (2.00–7.75)</td>
<td>&lt;.001</td>
<td>1.49 (66–336)</td>
<td>.332</td>
<td>1.64 (.69–3.91)</td>
</tr>
<tr>
<td>Sibling(s) use EC</td>
<td>96 (3.9)</td>
<td>.51 (.16–161)</td>
<td>.251</td>
<td>.36 (.06–211)</td>
<td>.258</td>
<td>.27 (.04–193)</td>
</tr>
<tr>
<td>No</td>
<td>899 (8.3)</td>
<td>1.00</td>
<td>—</td>
<td>—</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>31 (29.9)</td>
<td>4.60 (1.50–14.66)</td>
<td>.008</td>
<td>1.46 (39–543)</td>
<td>.576</td>
<td>.92 (28–309)</td>
</tr>
<tr>
<td>NA/DK</td>
<td>90 (5.6)</td>
<td>.66 (.23–183)</td>
<td>.420</td>
<td>1.03 (21–511)</td>
<td>.969</td>
<td>1.10 (.19–627)</td>
</tr>
<tr>
<td>Public approve of smoking</td>
<td>1000 (9.0)</td>
<td>1.00</td>
<td>—</td>
<td>—</td>
<td>1.00</td>
<td></td>
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<tr>
<td>No</td>
<td>20 (2.8)</td>
<td>.29 (.04–222)</td>
<td>.233</td>
<td>.09 (.01–.88)</td>
<td>.038</td>
<td>.15 (.02–122)</td>
</tr>
<tr>
<td>Yes</td>
<td>995 (8.5)</td>
<td>1.00</td>
<td>—</td>
<td>—</td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>

Adjusted model 1 constant OR = 0.02 (95% CI = 0.00–.07) p < .001. Adjusted model 2 constant OR = 0.02 (95% CI = 0.00–10), p < .001. N and % illustrate the number and percentage of individuals who initiated EC use at follow-up. All n use unweighted data, % and analyses use weighted data. Significant associations (p < .05) are highlighted in bold.

* Adjusted model 1 is adjusted for all variables listed except follow-up smoking.
† Adjusted model 2 is adjusted for all variables listed.
‡ Mean (SD) reported, mean (SD) for never used EC at follow-up: school performance = 3.08 (.8), problem behavior = 2.77 (1.0).
findings that ever e-cigarette use was largely confined to those who had ever smoked, with a low proportion of never smokers having ever used e-cigarettes, was consistent with other findings in Great Britain [5,35]. Furthermore, only 4% of never smokers initiated e-cigarette use (vs. 32% of ever smokers). This suggests that e-cigarettes are attracting few who have never smoked. Furthermore, monthly or more smoking and e-cigarette use was low, at 5% and 2%, respectively.

In the logistic regression analyses, e-cigarette escalation between baseline and follow-up was associated with smoking initiation, even when controlling for ever e-cigarette use; likewise, smoking escalation was associated with e-cigarette initiation when controlling for ever smoking. This represents a novel contribution to the literature, and further suggests the need for multi-wave surveys to explore dynamic changes in use of both products over time. Despite this, the causal mediation analyses, which as discussed allow for stronger conclusions to be made regarding observed observations, suggest that it is primarily ever use of that product that contributes to initiation of the alternative product.

Our findings are consistent with previous studies that found a prospective association between e-cigarette use at baseline and smoking at follow-up [4,12–21], and also with those who found a prospective association between smoking at baseline and e-cigarette use at follow-up [18,24]. There are several possible reasons for the strong and reliable association between e-cigarettes and smoking in young people [18,28,36]. One interpretation is that e-cigarettes act as a “gateway” to smoking [3,37]; however, this has been contested [28,36], and our findings suggest that the association between e-cigarette initiation and smoking initiation may work both ways. Certain psychological processes (“common liabilities”) may lead to vulnerability of any drug use [22,23]. Specifically, young people who exhibit curiosity, rebelliousness, and sensation-seeking may be more likely to experiment with both smoking and e-cigarettes. Future research should explore potential common liabilities pertaining to experimentation of both products, some of which were included in this study and others are proposed above.

Despite potential common liabilities and our findings that e-cigarette use is associated with smoking and vice versa, there are several important differences to consider between these products and the contexts in which they may be used. Among young people, e-cigarettes, compared with conventional cigarettes, have been described as more accessible and convenient [38,39], have a greater capacity for continual novelty in terms of flavors and devices [39], and are perceived as less harmful in the UK [5,39]. On the contrary, smoking is highly stigmatized in some societal groups [40]. Indeed, some have reported that e-cigarettes appeal to those who do not want to smoke but want to try the experience of “smoking” [38,39].

Interestingly, friend’s e-cigarette use increased the likelihood of e-cigarette initiation but reduced the likelihood of smoking initiation in adjusted models. This first association is unsurprising given the important role of peer influence on behavior. However, the protective effect of friend’s e-cigarette use on smoking initiation warrants further investigation.

In conclusion, this study provides further support for the association between ever e-cigarette use and smoking initiation, and additionally finds that even smoking is associated with e-cigarette initiation, among young people. Better understanding of these associations will aid policy makers with their efforts to develop an appropriate regulatory framework for both tobacco products and e-cigarettes.

Funding Sources

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Supplementary Data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jadohealth.2017.11.301.

References


