



E-Cigarette Use Among High School Students—a Cross-Sectional Study of Associated Risk Factors for the Use of Flavour-Only and Nicotine Vapes

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Abstract

The aim of this study is to examine e-cigarette use among high school students and the associated risk factors for the use of flavour-only or nicotine vapes. Grade 12 students ($N=855$) of 2020 from nine Australian schools completed a cross-sectional self-report survey. Correlates examined included age, gender, Aboriginal or Torres Strait Islander, parental and family characteristics, truancy, mental health (depression and anxiety), alcohol use and cigarette smoking. Overall, 74% reported that they had never used an e-cigarette or vaped, 12.5% had for flavour-only, and 13.5% had for nicotine vapes. Multinomial adjusted logistic regressions showed that males and teens reporting frequent alcohol or cigarette use had higher odds of vaping. In adolescents who had used an e-cigarette, half had used a nicotine vape. Those who engaged in risky drinking and smoked cigarettes were most likely to also use e-cigarettes, implying that this may be a high-risk group.

Keywords E-cigarette · Vaping · Nicotine · Smoking · Adolescents · Cross-sectional

Prevalence of e-cigarette use among adolescents has been increasing in several countries around the world (Lyzwinski et al., 2022). Most existing studies of e-cigarette use in youth are from the USA, Canada and the UK, and there is a lack of studies on vaping among adolescents from other countries with an increasing trend, including Australia.

Population survey data from the Australian National Drug Strategy Household Survey found that the proportion of youth aged 14–19 years who vaped increased from 1.5% in 2016 to 2.8% in 2019, while lifetime use increased from 12.6 to 14.5% (Australian Institute of Health & Welfare, 2020). The 2020–2021 Australian National Health

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Survey found 7.6% of people aged 15–17 years had used an e-cigarette at least once (Australian Bureau of Statistics, 2022). Close to Australia, a New Zealand study found vaping prevalence increasing from 2014 to 2019, for both those who had ever tried it (20.8 to 37.3%) and those who vaped daily (1.1 to 3.1%) (Walker et al., 2020). The study also reported that those who vaped were more likely to be male or gender-diverse, Maori/Pasifika and from low and mid-decile schools, indicating sociodemographic factors are associated with e-cigarette use.

There have been concerns that vaping is a gateway to cigarette smoking. For example, a recent meta-analysis found that there was a longitudinal association between vaping and cigarette smoking, but findings were limited by inadequate adjustment for confounders, high sample attrition and publication bias (Chan et al., 2021). Thus, the association between cigarette smoking and vaping warrants additional research.

Other factors associated with vaping are mental health problems, alcohol use and family-related factors. A systematic review found that in adolescents, e-cigarette use was associated with depression and externalising disorders (Becker et al., 2021). Those who used e-cigarettes also had higher anxiety, though not to a significant extent (Becker et al., 2021). Both internalising and externalising problems have been found to increase odds of adolescents initiating exclusive e-cigarette use (Buu et al., 2021). Regarding alcohol use, a previous study found that those who used e-cigarettes have 6.5 times greater odds of lifetime alcohol use and binge-drinking compared to non-users (Rothrock et al., 2020). For family-related factors, there could be a range of variables associated, for example, studies have found that family conflict was associated with e-cigarette use (Eslava et al., 2022; Finan et al., 2022). Parental divorce also appears to have an association with e-cigarette use (Fortier et al., 2022; Kinnunen et al., 2018; Melka et al., 2019a; Watkins & Ohannessian, 2020), though one Canadian longitudinal study found a lack of significant association after adjusting for household income and adolescent age (Fortier et al., 2022). Lower grades at school and truancy are additional factors associated with e-cigarette use (Gilbert et al., 2021; Kinnunen et al., 2016; McCabe et al., 2017; Orr et al., 2020; Williams et al., 2021). Notably, many existing studies on e-cigarette use did not specify whether the vapes were flavour-only or contained nicotine.

The current study investigated e-cigarette use among adolescents in Australia, where there have been concern about its increasing trend, but a lack of studies conducted. It identified factors cross-sectionally associated with e-cigarette use in Grade 12 school students, differentiating between flavour-only and nicotine vapes. Increased information on profiles of adolescents who are at risk of harms associated with e-cigarette use would enable appropriate support and intervention strategies to be implemented.

Methods

Study Design

This paper employed a cross-sectional study design using self-report survey data. It is a secondary data analysis study of data collected in 2020 from Grade 12 students attending nine independent high schools across South East Queensland, Australia, as part of the Adolescent Aware project.

Setting

The Adolescent Aware project is a 6-year longitudinal school-based study run by researchers from the Queensland University of Technology (QUT) and University of Queensland (UQ). The Adolescent Aware project aimed to investigate factors underlying bullying, underage drinking, substance use and wellbeing in adolescence by collecting self-reported survey data from the same two cohorts of students on an annual basis, from 2015 (when students were in Grade 7 and 8) to 2020 (when the youngest cohort reached Grade 12). Prior to each survey, passive parental consent and active student self-consent were obtained. Researchers visited participating schools to assist with administration during class time. After providing consent via pen and paper, students completed the 40- to 50-min survey online. Students unable to complete the survey online (e.g. due to internet issues, laptop uncharged) were provided a hard copy survey. All procedures followed were in accordance with the ethical standards of the Queensland University of Technology (#1,500,000,151) and The University of Queensland (#2,018,000,860) Human Research Ethics Committees.

Participants

Of the 1069 students enrolled in Grade 12 at the participating schools in 2020, 214 (20.02%) did not participate (absent=119, parental opt-out=33, no response=60, provided consent but no data=2). The participants of the current study included 855 (79.98%) Grade 12 students in 2020. Students individually completed the surveys in school group settings from 12 June to 12 October 2020. Participating students were entered in the draw to win an iPad 7th Gen 10.2" WiFi 32 GB for completing the survey.

E-Cigarette Use

The students self-reported on whether they had ever used an e-cigarette or vaped, even once or twice. The students were provided with the following information: ‘The following section is about electronic cigarettes or e-cigarettes. E-cigarettes are battery powered devices that contain a liquid (may contain flavouring with or without nicotine) that is vaporised and inhaled. You may also know them as e-cigs, vape-pens, e-pipes or personal vaporisers. The use of e-cigarettes is sometimes referred to as “vaping”’. Among those who had, they were asked to report if they had tried flavour-only or nicotine vapes. E-cigarette use status was categorised into three groups: (1) never tried; (2) tried flavour-only (had not tried nicotine vapes); (3) tried nicotine vapes (includes those who tried both flavour-only and nicotine vapes). If they had tried a nicotine vape, they were included in the nicotine vapes group.

Associated Factors

Associated factors examined included age, gender, Aboriginal or Torres Strait Islander status, parental and family characteristics, history of truancy in the past year, academic grade, depressive and anxiety symptoms, alcohol use and cigarette smoking. All of these associated factors were analysed as exposure variables.

Age was dichotomised into a binary variable because the students were either aged 17 or 18 as they were Grade 12 students. All students reported as being either male

or female. Parental and family characteristics variables examined included parental country of birth, parental relationship status and number of family vehicles as a proxy measure of socioeconomic status. Truancy was based on self-reports of having one or more days off in the past year without parents' permission.

Depressive symptoms were measured using the Patient Health Questionnaire-8 (PHQ-8). The PHQ-8 is an 8-item validated self-report measure assessing eight of the nine criteria required for a diagnosis of DSM-5 depressive disorders (Kroenke et al., 2009). Students scored the frequency of symptoms experienced over the past 2 weeks on a 4-point scale from 0 'Not at all' to 4 'Nearly every day'. Responses across all eight questions were summed to create a total severity score. Based on the scores, levels of depressive symptoms were defined as low to mild for scores 0–9 and moderate-high for scores 10 or higher (Kroenke et al., 2001). The PHQ-8 was found to be highly reliable in the current study (8 items; $\alpha=0.91$).

Anxiety was measured using the Social Anxiety Scale for Adolescents (SAS-A), which incorporates the Fear of Negative Evaluation (FNE) and Social Avoidance and Distress General (SAD-G). The SAS-A assesses concerns, fears and worries regarding negative evaluation from others and generalised/severe social distress, discomfort and inhibition, and is a validated measure of social anxiety among adolescents (Storch et al., 2004). The scale includes 12 statements (8 FNE, 4 SAD-G) with students indicating how 'true' the statement is for them, on a 5-point rating scale from 1 'Not at all' to 5 'All the time'. Scores on the FNE and SAD-G were summed to create a total score ranging from 12 to 60, with higher scores indicating a greater level of social anxiety. The SAS-A had an overall high reliability across these 12 items ($\alpha=0.95$). Scores were recoded into a binary variable with scores of 36 (mid-point score) or lower as low-average social anxiety and 37 or higher as high social anxiety. Findings on the association between social anxiety and e-cigarette use were consistent between the continuous score and the binary variable (scores were $M=28.51$ [$SD=12.09$], $M=26.62$ [11.53] and $M=28.09$ [12.25] in the never, flavour-only and nicotine vapes groups respectively, $p=0.345$). For ease of interpretation, we present findings based on the dichotomised variable.

Frequent alcohol use was measured by an item that asked students how often they have had a drink containing alcohol in the past 12 months, for which we coded participants' alcohol use as frequent (2–3 times a month/2–3 times a week/4+ times a week) versus not frequent (never/monthly or less). Cigarette use was categorised as never (never had a full cigarette), occasionally (less frequent than weekly) and weekly or daily (regularly).

Statistical Analysis

Descriptive statistics were calculated to report the proportion of students using e-cigarettes in the three categories (never tried, tried flavour-only, tried nicotine vapes). Bivariate associations between e-cigarette use and associated factors were examined by cross-tabulations and chi-squared tests. Multinomial regression analyses were conducted to examine the adjusted odds ratios of having used flavour-only and having used a nicotine vape (never tried as reference) by the associated factors. One regression analysis was conducted with all the associated factors included as exposure variables in the model. The analyses were conducted using SPSS v28.

Results

Levels of Missing Data

Levels of missing data were low for each variable (all were under 5%; see Table S1). There were 41 (4.8%) cases of missing data on e-cigarette use. Males (7.0% missing) were more likely to have missing data on e-cigarette use than females (1.5% missing, $p < 0.001$). No other student characteristics, familial, schooling, mental health (depression and anxiety) and alcohol and cigarette use variables were associated with missing data on e-cigarette use (see Table S2). Among those with data on e-cigarette use, males were more likely to have ever used an e-cigarette ($p < 0.001$; see Figure S3). Therefore, to reduce potential bias due to missing data, multiple imputations were used to impute for missing data. Compared to the original dataset, the imputed dataset had a slightly higher proportion of students who had tried or used a vape, but with overlapping confidence intervals (see Table S4). The results reported below are from analyses using the multiple imputed dataset of the full sample of 855 students.

Participant Characteristics

The majority of our sample was 17 years old, and a minority was 18 years old. The sample had more males than females. A small proportion of participants identified as Aboriginal or Torres Strait Islander. Over half had both parents born in Australia, a quarter reported that their parents were not living together, and most students had two or more family vehicles. A small proportion had a history of truancy. A minority had moderate or high levels of depressive or social anxiety symptoms. Under half reported frequent alcohol use, and most had never had a full cigarette. The mean age of first having smoked a full cigarette ($M = 15.43$, $SD = 1.54$) was slightly younger than the mean age of having first tried an e-cigarette or vape ($M = 15.80$, $SD = 1.29$; t -test $p = 0.044$).

Overall, 74% of participants reported that they had never tried or used an e-cigarette, 12.5% reported having used a flavour-only vape, and 13.5% reported having tried or used nicotine vapes (Table 1).

Bivariate Associations

Cross-tabulation results showed that e-cigarette use significantly differed by gender, history of truancy, alcohol use and cigarette use (see Table 2). More males had tried or used e-cigarettes than females ($p < 0.001$). A quarter of students with a history of truancy had used nicotine vapes, compared to one in ten among students with no history of truancy ($p < 0.001$). Students who engaged in frequent alcohol use were more likely to have used flavour-only or nicotine vapes ($p < 0.001$). Students who smoked cigarettes occasionally were most likely to have tried or used flavour-only vapes, and students who smoked cigarettes weekly or daily were most likely to have used nicotine vapes ($p < 0.001$). E-cigarette use was not significantly associated with parental country of birth, parental relationship status, number of family vehicles, academic grade or depressive and anxiety symptoms.

Table 1 Descriptive statistics of participant characteristics ($N=855$)

| | % | 95% CI |
|--------------------------------------|-------|------------|
| Age | | |
| 17 years old | 82.2% | 79.4–85.0% |
| 18 years old | 17.8% | 11.7–23.9% |
| Gender | | |
| Male | 60.4% | 56.2–64.6% |
| Female | 39.6% | 34.4–44.8% |
| Aboriginal or Torres Strait Islander | | |
| No | 96.5% | 95.2–97.7% |
| Yes | 3.5% | 0.0–10.1% |
| Parental country of birth | | |
| Both born in Australia | 60.5% | 56.3–64.7% |
| One parent born in Australia | 20.2% | 14.2–26.2% |
| Neither born in Australia | 19.4% | 13.3–25.4% |
| Parental relationship status | | |
| Living together | 75.1% | 71.7–78.4% |
| Not living together | 24.9% | 19.1–30.7% |
| Family vehicles | | |
| Two or more | 91.2% | 89.2–93.2% |
| One or none | 8.8% | 2.4–15.2% |
| Truancy | | |
| No | 87.4% | 85.0–89.8% |
| Yes | 12.6% | 6.4–18.9% |
| Academic grade | | |
| A | 21.7% | 15.7–27.6% |
| B | 51.5% | 46.8–56.1% |
| C or lower | 26.9% | 21.1–32.6% |
| Depressive symptoms | | |
| Low-mild | 69.5% | 65.8–73.2% |
| Moderate-high | 30.5% | 24.9–36.0% |
| Social anxiety symptoms | | |
| Low-average | 77.8% | 74.6–80.9% |
| High | 22.2% | 16.3–28.1% |
| Frequent alcohol use | | |
| No | 58.2% | 53.8–62.5% |
| Yes | 41.8% | 36.7–46.9% |
| Cigarette smoking | | |
| Never a full cigarette | 79.4% | 76.4–82.5% |
| Yes, occasionally | 14.9% | 8.7–21.1% |
| Yes, weekly or daily | 5.6% | 0.0–12.1% |
| E-cigarette use | | |
| Never tried/used | 74.0% | 70.6–77.4% |
| Tried/used flavour-only | 12.5% | 6.2–18.7% |
| Tried/used nicotine vapes | 13.5% | 7.3–19.8% |

Table 2 Cross-tabulation of e-cigarette use by associated factors

| | E-cigarette use % (95% CI) | | | Chi-sq |
|---|----------------------------|-------------------------|---------------------------|----------|
| | Never tried/used | Tried/used flavour-only | Tried/used nicotine vapes | <i>p</i> |
| Age | | | | |
| 17 years old | 75.1% (71.9–78.3%) | 12.0% (9.6–14.4%) | 12.9% (10.5–15.4%) | 0.231 |
| 18 years old | 69.1% (61.7–76.4%) | 14.7% (9.1–20.4%) | 16.2% (10.3–22.0%) | |
| Gender | | | | |
| Male | 69.5% (65.5–73.4%) | 15.5% (12.4–18.6%) | 15.1% (12.0–18.1%) | <0.001 |
| Female | 81.0% (76.8–85.2%) | 7.9% (5.0–10.7%) | 11.2% (7.8–14.5%) | |
| Aboriginal or Torres Strait Islander | | | | |
| No | 73.9% (70.9–76.9%) | 12.5% (10.3–14.8%) | 13.6% (11.3–15.9%) | 0.849 |
| Yes | 78.0% (63.2–92.8%) | 10.7% (0.0–21.7%) | 11.3% (0.0–22.7%) | |
| Parental country of birth | | | | |
| Both born in Australia | 74.6% (70.8–78.3%) | 11.5% (8.7–14.2%) | 13.9% (10.9–16.9%) | 0.629 |
| One parent born in Australia | 71.0% (64.2–77.8%) | 14.6% (9.3–19.9%) | 14.4% (9.1–19.6%) | |
| Neither born in Australia | 75.4% (68.8–81.9%) | 13.3% (8.1–18.5%) | 11.4% (6.5–16.2%) | |
| Parental relationship status | | | | |
| Living together | 73.9% (70.5–77.3%) | 12.7% (10.2–15.3%) | 13.4% (10.8–16.0%) | 0.863 |
| Not living together | 74.5% (68.6–80.3%) | 11.6% (7.3–16.0%) | 13.9% (9.3–18.5%) | |
| Family vehicles | | | | |
| Two or more | 72.9% (69.8–76.0%) | 13.0% (10.7–15.4%) | 14.1% (11.6–16.5%) | 0.053 |
| One or none | 85.6% (77.7–93.5%) | 6.7% (1.0–12.3%) | 7.7% (1.7–13.8%) | |
| Truancy | | | | |
| No | 76.5% (73.5–79.6%) | 11.7% (9.4–14.0%) | 11.8% (9.4–14.1%) | <0.001 |
| Yes | 56.7% (47.3–66.0%) | 17.6% (10.4–24.8%) | 25.7% (17.5–34.0%) | |
| Academic grade | | | | |
| A | 79.6% (73.8–85.4%) | 10.9% (6.4–15.4%) | 9.5% (5.3–13.7%) | 0.129 |
| B | 73.4% (69.2–77.5%) | 11.8% (8.8–14.8%) | 14.8% (11.5–18.1%) | |
| C or lower | 70.8% (64.9–76.6%) | 15.0% (10.4–19.6%) | 14.3% (9.8–18.8%) | |
| Depressive symptoms | | | | |
| Low-mild | 75.4% (72.0–78.9%) | 11.7% (9.2–14.3%) | 12.8% (10.1–15.5%) | 0.386 |
| Moderate-high | 70.7% (65.2–76.3%) | 14.1% (9.9–18.4%) | 15.1% (10.8–19.5%) | |
| Social anxiety symptoms | | | | |
| Low-average | 72.8% (69.4–76.1%) | 13.4% (10.8–16.0%) | 13.8% (11.2–16.5%) | 0.193 |
| High | 78.4% (72.6–84.3%) | 9.2% (5.1–13.3%) | 12.4% (7.7–17.1%) | |
| Frequent alcohol use | | | | |
| No | 87.3% (84.3–90.2%) | 8.4% (6.0–10.8%) | 4.3% (2.6–6.1%) | <0.001 |
| Yes | 55.6% (50.4–60.7%) | 18.1% (14.1–22.1%) | 26.3% (21.7–30.8%) | |
| Cigarette smoking | | | | |
| Never a full cigarette | 85.2% (82.5–87.9%) | 10.3% (8.0–12.6%) | 4.5% (2.9–6.1%) | <0.001 |
| Yes, occasionally | 35.1% (26.8–43.4%) | 24.3% (16.9–31.7%) | 40.6% (32.1–49.1%) | |
| Yes, weekly or daily | 19.5% (8.3–30.7%) | 11.6% (2.6–20.7%) | 68.9% (55.8–82.0%) | |

Multinomial Regression Results

Results of the multinomial regression with all variables included revealed that gender was a significant predictor of using flavour-only vapes, but gender was not significantly associated with using nicotine vapes (see Table 3). Specifically, males had 2.26 (1.28–3.99) times higher odds of having tried or used flavour-only vapes than females. Students with a history of truancy had higher odds of using e-cigarettes than students without a history of truancy, but this was not statistically significant.

Adolescents who engaged in frequent alcohol use had over 2 times significantly higher odds of using flavour-only vapes ($OR=2.14$ [1.28–3.57]) and over 3 times significantly higher odds of using nicotine vapes ($OR=3.26$ [1.37–7.80]). Students who smoked cigarettes occasionally had almost 4 times significantly higher odds of using flavour-only vapes ($OR=3.92$ [2.20–6.99]) and over 15 times higher odds of having used nicotine vapes ($OR=16.07$ [6.29–41.08]). Those who smoked cigarettes weekly or daily had higher odds of using flavour-only vapes as well, which however was not statistically significant ($OR=2.95$ [0.74–11.77]), but this group had over 40 times higher odds of using nicotine vapes ($OR=43.77$ [15.95–120.06]).

Discussion

We examined e-cigarette use and associated risk factors among Australian Grade 12 high school students of 2020. A novelty of our study is that we had information to examine and compare potential differences in the profiles of adolescents who used flavour-only vapes compared to those who used nicotine vapes. Many existing studies of e-cigarette use among adolescents have not differentiated the content of vapes in their research. When flavoured vapes have been studied in the past, whether they were nicotine-free or not has generally not been distinguished, but flavoured vapes have been associated with an increased risk of prolonged e-cigarette use (Notley et al., 2022). It is important to examine what substances adolescents are vaping because the use of nicotine vapes has direct implications for addiction, while the use of flavour-only vapes does not.

Our results showed that adolescents who engaged in other addictive behaviours, including frequent alcohol use and cigarette smoking, were at increased risk of e-cigarette use, particularly for vaping e-cigarettes containing nicotine. US studies have reported that people who smoked were more likely to use nicotine over nicotine-free vapes (Krishnan-Sarin et al., 2015). Recent studies of Australian youth have found an overall preference for nicotine-containing vapes over nicotine-free vapes, particularly in those who smoked, including in adolescents (Jongenelis, 2023; Jongenelis et al., 2018). The use of nicotine-containing vapes may pose as a more serious concern than flavour-only vapes due to their addictive element. Adolescents who are experimenting with common substances, like alcohol and cigarettes, may be more open to also trying e-cigarettes. Adolescents who are at risk for using one substance may be at risk of using several other substances. We found that male gender was associated with the higher risk category, which is consistent with existing adolescent health research findings that males typically engage in more risky behaviours than females.

We found that in 2020, 26% of students had tried or used an e-cigarette before, and among those who had, about half had used vapes containing nicotine. The prevalence

Table 3 Multinomial regression on e-cigarette use

| | Odds ratios of e-cigarette use (ref: never tried/used) | | | |
|---|--|----------|---------------------------|----------|
| | Tried/used flavour-only | | Tried/used nicotine vapes | |
| | OR (95% CI) | <i>p</i> | OR [95% CI] | <i>p</i> |
| Age | | | | |
| 17 years old | 0.82 (0.46–1.46) | 0.491 | 0.81 (0.42–1.55) | 0.524 |
| 18 years old | 1.00 (ref) | | 1.00 (ref) | |
| Gender | | | | |
| Male | 2.26 (1.28–3.99) | 0.005 | 1.64 (0.71–3.79) | 0.225 |
| Female | 1.00 (ref) | | 1.00 (ref) | |
| Aboriginal or Torres Strait Islander | | | | |
| Yes | 0.70 (0.20–2.49) | 0.584 | 0.68 (0.17–2.74) | 0.586 |
| No | 1.00 (ref) | | 1.00 (ref) | |
| Parental country of birth | | | | |
| Both born in Australia | 1.00 (ref) | | 1.00 (ref) | |
| One parent born in Australia | 1.23 (0.69–2.20) | 0.478 | 1.13 (0.50–2.56) | 0.771 |
| Neither born in Australia | 1.18 (0.67–2.10) | 0.566 | 1.00 (0.50–2.01) | 0.999 |
| Parental relationship status | | | | |
| Living together | 1.00 (ref) | | 1.00 (ref) | |
| Not living together | 0.85 (0.50–1.44) | 0.553 | 0.76 (0.40–1.44) | 0.402 |
| Family vehicles | | | | |
| Two or more | 1.67 (0.55–5.12) | 0.366 | 1.13 (0.32–4.05) | 0.847 |
| One or none | 1.00 (ref) | | 1.00 (ref) | |
| Truancy | | | | |
| No | 1.00 (ref) | | 1.00 (ref) | |
| Yes | 1.37 (0.70–2.70) | 0.360 | 1.18 (0.51–2.75) | 0.690 |
| Academic grade | | | | |
| A | 1.00 (ref) | | 1.00 (ref) | |
| B | 1.18 (0.65–2.15) | 0.580 | 1.57 (0.75–3.29) | 0.233 |
| C or lower | 1.30 (0.67–2.52) | 0.429 | 1.26 (0.53–3.04) | 0.598 |
| Depressive symptoms | | | | |
| Low-mild | 1.00 (ref) | | 1.00 (ref) | |
| Moderate-high | 1.42 (0.83–2.40) | 0.197 | 0.84 (0.44–1.60) | 0.589 |
| Social anxiety symptoms | | | | |
| Low-average | 1.00 (ref) | | 1.00 (ref) | |
| High | 0.67 (0.35–1.27) | 0.215 | 1.22 (0.58–2.60) | 0.597 |
| Frequent alcohol use | | | | |
| No | 1.00 (ref) | | 1.00 (ref) | |
| Yes | 2.14 (1.28–3.57) | 0.004 | 3.26 (1.37–7.80) | 0.010 |
| Cigarette smoking | | | | |
| Never a full cigarette | 1.00 (ref) | | 1.00 (ref) | |
| Yes, occasionally | 3.92 (2.20–6.99) | <0.001 | 16.07 (6.29–41.08) | <0.001 |
| Yes, weekly or daily | 2.95 (0.74–11.77) | 0.123 | 43.77 (15.95–120.06) | <0.001 |

observed in our study (age 17–18, 2020) was higher than the prevalence reported in the latest Australian National Drug Strategy Household Survey (14.5% in youth aged 14–19, 2019) and the Australian National Health Survey (7.6% in youth aged 15–17, 2020–2021) (Australian Bureau of Statistics, 2022; Australian Institute of Health & Welfare, 2020). Our results are not directly comparable, because those population surveys were Australia-wide, whereas our study sampled several schools in South East Queensland. In addition, the age of the adolescents between the studies differed—we would expect a higher lifetime prevalence of e-cigarette use in older adolescents. Furthermore, the population-wide studies do not have a good representation of youth in general, because responses of household surveys often select an adult living in the household as the respondent. Among youth specific studies, a South Australian survey of 13–19-year-olds conducted in 2022 found significantly higher usage numbers than our current study. They found that 2 in 3 respondents had tried vaping, and 1 in 4 of those were vaping on most days (Connolly, 2022). These previous Australian studies had not assessed whether the vapes were nicotine or flavour-only, so a strength of our study is that we provided novel findings on the proportion of adolescents who reported that they had tried nicotine vapes among those who had used an e-cigarette.

In our study, we found that e-cigarette use was associated with truancy in the bivariate analyses, but not significantly in the multivariate analysis after controlling for other predictors. Both truancy and substance use may fall under a risk profile of adolescents that overall may be determined by common factors such as parental supervision that were not measured in the current study. Interventions and strategies to prevent truancy and substance use may have beneficial impacts on addressing e-cigarette use and broader adolescent development outcomes.

Consistent with evidence on the risk profiles of traditional cigarette use, males were at higher risk of vaping. However, in our adjusted regression model, there were no significant gender differences in having tried nicotine vapes. This is in contrast to studies in Australian and New Zealand university students that have found that men are more likely to vape (Heris et al., 2022; Wamamili et al., 2021). US studies have also reported that males were more likely to use nicotine vapes while females were more likely to vape flavour-only (Miech et al., 2017). We can compare our results with the broader substance use literature. Trends from the alcohol use literature in many countries, including Australia and the USA, have demonstrated a closing of the gender gap in risky alcohol use (Keyes et al., 2008; Livingston et al., 2018). Together, it may be that the prevalence of risky alcohol use and related behaviours used to be predominantly higher in males, but the gap has narrowed in recent years. Given the potential for a similar ‘closing gender gap’ trend to occur for vape use (Melka et al., 2019b), attention on preventing onset of regular vape use by female adolescents should also be a priority.

Our study found that cigarette smoking was the strongest predictor of nicotine vaping in adolescents. This reflects broader literature—for example, the 2017 national Australian Secondary School Students Alcohol and Drug survey (ASSAD) reported that 65% of students who had used e-cigarettes had also used tobacco cigarettes, with those who have ever smoked being 13 times more likely to have tried e-cigarettes (Heris et al., 2022). An analysis of the previous ASSAD survey in 2014 showed a similar trend (Williams & White, 2018). In the current literature, there have been questions around whether e-cigarette use is a risk factor for cigarette smoking, or whether cigarette smoking is the risk factor for e-cigarette use (Chan et al., 2021). In our study, the mean age of first having smoked a full cigarette ($M = 15.43$, $SD = 1.54$) is slightly younger than the mean age of having first tried an e-cigarette or vape ($M = 15.80$, $SD = 1.29$; $p = 0.044$). Based on the age of initiation, there is a potential causal pathway, whereby cigarettes could be a ‘gateway’ substance to

e-cigarette use. However, tobacco cigarettes have been commonly used in the society for far longer than e-cigarettes, which may explain the later age of initiation of e-cigarettes use. Other studies have suggested that e-cigarette use does not predict onset of tobacco cigarette smoking among young people. For example, in England where the trend of e-cigarette use began earlier than in Australia, time-series analysis of population trend data showed that prevalence of e-cigarette use was not associated with changes in the prevalence of smoking uptake in youth (Beard et al., 2022). Similarly, in the USA, an increase in the prevalence of e-cigarette use was not followed by an increase in traditional cigarette use, which continued to decline (Sun et al., 2021). Regardless of whether e-cigarette use causes smoking uptake or not, e-cigarette use should be discouraged in adolescents, because e-cigarettes and vapes, with or without nicotine, contain harmful chemicals that can have negative impacts on adolescent health (Larcombe et al., 2022).

This study did not find associations between e-cigarette use and depressive or anxiety symptoms. Previous studies have found that cigarette smoking is associated with psychological distress, including in Australian population studies (Leung et al., 2011). Studies from the USA have shown that psychological distress was associated with both cigarette and e-cigarette use (Weinberger et al., 2020). A Norwegian study found that the use of nicotine vapes was associated with depressive symptoms and conducts problems in adolescents (Tokle et al., 2022). However, results of the current study were neither consistent with psychological distress increasing the risk of e-cigarette use by adolescents nor with e-cigarettes impacting on levels of psychological distress. Our null finding may also be explained by the low levels of e-cigarettes use in our sample, which reduces power to detect an association between e-cigarette use and psychological symptoms. Adolescents with more severe psychological symptoms may also be likely to be under-represented in our study if they were not at school at the time of data collection. In addition, if smoking e-cigarettes has psychological impacts on adolescents, it may be difficult to detect this in our study, due to insensitivity of the item measuring e-cigarette use. This item asked participants to report if they had ever used an e-cigarette or vape, but did not differentiate between adolescents who had only tried vaping once or twice and those who may have been vaping regularly. The latter is the group that requires attention, because if there are any psychological or other impacts of e-cigarette use, it is unlikely to happen if they were only used once or twice. An important goal of future research on adolescent e-cigarette use should be an investigation of the effects of repeated e-cigarette use by adolescents and young adults.

Key limitations of this study are its cross-sectional design, which limits ability to infer causality of results, its measurement of e-cigarette use, its limitation to students attending independent schools and the use of an indirect index of socioeconomic status (multiple car ownership). There are limitations in how e-cigarette use was measured because the questionnaire was insensitive regarding the frequency of their use. Future studies that better capture and differentiate those who have only tried e-cigarettes compared to those who use them frequently are warranted.

The justification of using the number of family vehicles as a proxy measure of socioeconomic status is not strong. We found that the proportion of adolescents who had used e-cigarettes was higher among those from families with two or more vehicles than those from families with none or only one vehicle, but the result was not statistically significant. It could be that adolescents from families with two or more vehicles were from families of higher affluence, but it could also be impacted by area of residence. A previous UK study found no significant association with adolescent e-cigarette use and socioeconomic status (Conner et al., 2019). Future Australian studies could use better measures of individual

and area level socioeconomic status to examine any potential disparities in e-cigarette use. Future studies could also build upon our results by employing a longitudinal design, widening recruitment to include students from government-funded schools and more fully examining the effects of socioeconomic status and area of residence.

Our data were collected in 2020, which was during the COVID-19 pandemic. Compared to some other countries internationally and compared to some other states in Australia (New South Wales and Victoria), Queensland was relatively less impacted by the pandemic and data were collected after students returned to schools following a brief closure. Although Queensland was less impacted, the COVID-19 pandemic and associated precautions may have delayed the uptake of vaping due to reduced access and social interaction opportunities. The age of the data is a limitation, but our study still provided more recent data than the latest Australian population substance use survey, the 2019 National Drugs Strategy Household Survey. However, an increasing trend of vaping uptake has been reported by teachers and Australian media outlets (Pollard, 2022), so studies with more recent data are warranted to provide empirical evidence on current trends and risk factors. This paper can be used as a source of comparisons for future studies when more updated research becomes available.

We attempted to increase the external validity by sampling from multiple sites; however, all schools were from independent schools in South East Queensland, so results on prevalence cannot be generalised to all high school students in Australia or in other countries. However, we have no reason to suspect that factors associated with increased risks of e-cigarette use would not apply to other adolescent samples. The findings on correlates should have good external validity for providing important insights into risk factors of e-cigarette use among high school students, which can inform prevention and intervention efforts targeted towards this population.

Future research is warranted because the scope of our study focused on rates of e-cigarette use by adolescents in Australia and, most importantly, whether adolescents tend to use flavour-only or nicotine containing e-cigarettes. This study examined adolescents' use of vaping devices in terms of being potentially addictive, with nicotine-containing products classified as higher risk. However, vaping devices are a route of administration that can be used for a broader variety of substances (e.g. cannabis). Studies from North America have showed an increasing trend of cannabis vaping among adolescents, which is of public health concern (Lim et al., 2022). Australian studies that monitor trends of using vaping devices for other potentially more harmful substances are warranted.

Conclusions

Among the adolescents who had tried an e-cigarette, half had only tried a flavour-only vape, and the other half had tried a nicotine vape. Those who engaged in risky drinking and cigarette smoking were most likely to also use e-cigarettes, implying that this may be a high-risk group who are at risk of a broader range of risky behaviours and may benefit from targeted support and preventive interventions. Future studies of follow-up data to examine longer term impacts and trends of e-cigarette use and other substance use are warranted.

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Data Availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics Approval and Consent to Participate All procedures followed were in accordance with the ethical standards of Human Research Ethics Committees (approval obtained from Queensland University of Technology [1500000151] and The University of Queensland [2018000860]) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consent was obtained from all patients for being included in the study.

Conflicts of Interest The authors declare no competing interests.

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