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Adolescent substance use and educational attainment: An integrative data analysis comparing cannabis and alcohol from three Australasian cohorts*

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ABSTRACT

Background: The relative contributions of cannabis and alcohol use to educational outcomes are unclear. We examined the extent to which adolescent cannabis or alcohol use predicts educational attainment in emerging adulthood. Methods: Participant-level data were integrated from three longitudinal studies from Australia and New Zealand (Australian Temperament Project, Christchurch Health and Development Study, and Victorian Adolescent Health Cohort Study). The number of participants varied by analysis (N=2179-3678) and were assessed on multiple occasions between ages 13-25. We described the association between frequency of cannabis or alcohol use prior to age 17 and high school non-completion, university non-enrolment, and degree non-attainment by age 25. Two other measures of alcohol use in adolescence were also examined. Results: After covariate adjustment using a propensity score approach, adolescent cannabis use (weekly+) was associated with 1½ to 2-fold increases in the odds of high school non-completion (OR=1.60, 95%CI=1.09-2.35), university non-enrolment (OR=1.51, 95%CI=1.06-2.13), and degree non-attainment (OR=1.96, 95%CI=1.36-2.81). In contrast, adjusted associations for all measures of adolescent alcohol use were inconsistent and weaker. Attributable risk estimates indicated adolescent cannabis use accounted for a greater proportion of the overall rate of non-progression with formal education than adolescent alcohol use. Conclusions: Findings are important to the debate about the relative harms of cannabis and alcohol use. Adolescent cannabis use is a better marker of lower educational attainment than adolescent alcohol use and identifies an important target population for preventive intervention.

KEYWORDS: Cannabis; alcohol; adolescence; educational outcomes
1. **INTRODUCTION**

Successfully completing high school and attaining a university degree are critical developmental milestones linked to better health (Cutler and Lleras-Muney, 2010) and greater economic productivity (US Bureau of Labor Statistics, 2014). Alcohol and cannabis are commonly used by young people in the school-age years. Worldwide, 34% of 15-19 year olds are current drinkers (World Health Organization, 2014); European estimates suggest 12% of 15-16 year olds are past-month cannabis users although prevalence levels vary considerably between countries (European Monitoring Centre for Drugs and Drug Addiction, 2014). Adolescence may also be a vulnerable developmental period for the neurocognitive effects of substance use (Lisdahl et al., 2013). Heavy drinking and cannabis use have been linked to changes in central nervous system (CNS) structure and function in otherwise healthy adolescents (Lisdahl et al., 2013). Given the extent of exposure, the association of alcohol and cannabis use with subsequent levels of educational attainment is of increasing interest.

Research into the effects of cannabis has produced generally consistent findings to suggest that early use reduces the likelihood of progressing further in formal education (Macleod et al., 2004; Townsend et al., 2007). Typically, these associations attenuate but remain significant after controlling for potential confounding factors (e.g., socioeconomic status, family structure, peer behavior; Esch et al., 2014; Macleod et al., 2004). The picture is less clear in relation to alcohol use. Cross-sectional studies provide some evidence of an association between alcohol and educational attainment (Townsend et al., 2007), but the evidence from longitudinal studies is equivocal. Some have found little linkage between adolescent alcohol use and low school commitment (Hemphill et al., 2014),
years in education (Arria et al., 2013), and academic failure (Hemphill et al., 2014), after adjustment for potential confounders. Others have found early alcohol use is weakly associated with lower school grades (Crosnoe et al., 2012) and future educational achievement (Latvala et al., 2014), particularly for males (Balsa et al., 2011).

Two issues emerge in the literature. First, evidence of the effects of adolescent alcohol use on educational attainment is equivocal (McCambridge et al., 2011). Specifically, questions remain about the extent to which the apparent effects of adolescent drinking might be due to potential confounding factors not adequately controlled for in studies to date (McCambridge et al., 2011). Second, the relative contributions of cannabis or alcohol use to explaining non-progression with formal education have not been investigated.

We address these issues through the integration of data from three longitudinal studies from Australia and New Zealand: the Australian Temperament Study (ATP; Vassallo and Sanson, 2013), the Christchurch Health and Development Study (CHDS; Fergusson and Horwood, 2001), and the Victorian Adolescent Health Cohort Study (VAHCS; Patton et al., 2007). We integrated participant-level data rather than using the standard meta-analytic approach of combining study-level estimates. This approach increases sample size and statistical precision to investigate less common patterns of substance use (such as frequent use at a young age), provides the opportunity to include a wide range of potential confounding factors, and augments our ability to generalize findings to the region and internationally more realistically than is possible for any individual study (Curran and Hussong, 2009; Hofer and Piccinin, 2009). We build on earlier work which found that adolescent cannabis use was negatively associated with attaining secondary school and
tertiary qualifications (Horwood et al., 2010; Silins et al., 2014) and extend the analysis to examine the relative contributions of cannabis and alcohol use to educational outcomes.

We examined the extent to which adolescent cannabis or alcohol use was associated with non-progression with formal education using data from three Australasian cohort studies. Specifically, we: (1) investigated the association between both frequency of cannabis use and frequency of alcohol use prior to age 17 and high school non-completion, university non-enrolment, and degree non-attainment by age 25 in each study and in combined data; (2) examined two other patterns of alcohol use (amount consumed and number of alcohol-related problems) prior to age 17; (3) adjusted the associations for potential confounders drawn from similar domains across studies; and, (4) estimated the proportion of educational non-involvement attributable to adolescent cannabis or alcohol use if causality is assumed. The study has approval from the University of New South Wales Human Research Ethics Committee.

2. METHODS

2.1. Design and participants

Integrative analyses were developed across the three studies (Hutchinson et al., 2015): ATP (Vassallo and Sanson, 2013), CHDS (Fergusson and Horwood, 2001), and VAHCS (Patton et al., 2007). Additional information about the longitudinal cohorts is provided in Supplementary Material 1. Analyses were based on data from these studies assessed between ages 13-25. The number of participants varied by analysis (from 2179 to 3678).

1Supplementary material can be found by accessing the online version of this paper at http://dx.doi.org and by entering doi....
2.2. Measures

We assessed three educational outcomes in young people which reflect a general dimension of non-progression with formal education: high school non-completion, university non-enrolment, and degree non-attainment. We chose the outcomes based on research that established a link between educational achievement and the use of cannabis or alcohol in adolescence and the availability of similar measures across the cohorts. All studies obtained data on the completion of high school and university degree attainment. University enrolment was assessed only in CHDS and VAHCS. Using these data, a dichotomous variable was created for high school non-completion by age 25, university non-enrolment by age 21, and degree non-attainment by age 25 for each study with relevant data.

All studies included self-reported measures of frequency of cannabis or alcohol use during mid-adolescence over multiple assessments (Table 1). Using these data, a three-level measure of the maximum frequency of cannabis or alcohol use before age 17 was created for each study (never, less than weekly, weekly or more).

Two alternative measures of adolescent alcohol use were also harmonized. The CHDS and VAHCS assessed the amount of alcohol consumed on a typical drinking occasion and the average number of standard drinks consumed per day over multiple adolescent assessments, respectively. Using these data, a four-level measure of the maximum number of standard drinks consumed on a typical occasion before age 17 was created for each study (0-2 standard drinks, 3-6 standard drinks, 7-12 standard drinks, 13+ standard drinks).
The CHDS assessed the number of alcohol abuse/dependence symptoms, and the ATP and VAHCS asked about the frequency of a range of drinking-related problems across adolescence. Using these data, a four-level measure of the maximum number of alcohol-related problems before age 17 was created for each study (no problems, 1-2 problems, 3-4 problems, 5+ problems). Additional information about the derivation of harmonised variables is in Supplementary Material 2. We noted small between-study variations in the prevalence of adolescent substance use and some outcomes (Supplementary Material 3).

2.3. Potential confounding factors

We selected potential confounding factors from each study based on research suggesting that they might be correlated with both substance use and educational attainment. These factors spanned individual background and functioning (e.g., ethnicity, childhood attentional problems), and parental and peer factors (e.g., parental education, peer antisocial behaviour) (Supplementary Material 4).

2.4. Statistical analysis

The first analysis examined the bivariate associations between maximum frequency of cannabis or alcohol use before age 17 and the educational outcomes in each study and in

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2 Supplementary material can be found by accessing the online version of this paper at http://dx.doi.org and by entering doi:....

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the combined data set. We tested statistical significance by fitting a series of logistic regression models to the data for each study and the combined data in which the log odds of each outcome was modelled as a linear function of the three level measure of the frequency of either cannabis or alcohol use (Supplementary Material5). The model included study-specific random intercepts to allow for random sources of between study heterogeneity that were not otherwise reflected in the model. Effect size estimates (odds ratios and 95% confidence intervals) for each outcome were obtained from the models fitted to the combined data set.

In the second analysis, the bivariate associations were adjusted for confounding using a generalised propensity score approach (Imbens, 2000; Spreeuwenberg et al., 2010) in which the logistic regression models for the combined data were extended to incorporate study specific propensity scores (see Supplementary Material5). Propensity scores were estimated from a multinomial logistic regression in which the frequency of cannabis or alcohol use was regressed on the full set of available confounding factors in each study. To account for the comorbidity between cannabis and alcohol use, alcohol use was included as a predictor in the propensity model for cannabis use and vice versa. Propensity scores were then included in the fitted regression models and adjusted effect size estimates (ORs and 95% CIs) were obtained. These analyses were repeated using two alternative measures of

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5Supplementary material can be found by accessing the online version of this paper at http://dx.doi.org and by entering doi:....

6Supplementary material can be found by accessing the online version of this paper at http://dx.doi.org and by entering doi:....
adolescent alcohol use (Supplementary Material6). The risk of possible type I error due to multiple testing was small (i.e., we tested the associations between three highly correlated outcomes and each of four exposures) and no correction was made for multiple comparisons (Rothman, 1990).

Estimates of the covariate adjusted attributable risk (AR) of cannabis use and each of the measures of alcohol use were derived from the fitted models for each outcome in the combined data. AR estimates were obtained by generating the marginal adjusted rate of each outcome for each level of cannabis or alcohol use in the pooled data and these were used to provide direct estimates of the adjusted relative risk of educational non-involvement (Lee, 1981).

The above models assumed a linear effect of cannabis or alcohol use on the log odds of each outcome, and a common slope parameter for the effect of cannabis or alcohol use across studies. To test these assumptions, we first did Wald chi square tests to examine the improvement in fit of a categorical representation of cannabis or alcohol use over and above the linear model. We then extended the models to allow the slope parameter to vary across studies, and used Wald chi square to test for between-study heterogeneity in the effect of cannabis or alcohol use.

Finally, to examine the possible implications of selection bias from sample attrition and missing data in each study, the regression models were re-analysed using data

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6Supplementary material can be found by accessing the online version of this paper at http://dx.doi.org and by entering doi:...
weighting procedures (Little and Rubin, 2002; Supplementary Material 7). The results from the weighted and unweighted analyses were negligibly different, suggesting that selection bias was unlikely to have influenced the findings reported.

3. RESULTS

3.1. Associations between cannabis use, alcohol use and educational attainment

Table 2 shows the associations of maximum frequency of cannabis use and alcohol use, before age 17, classified in three levels (never, <weekly, weekly+) with the three measures of educational attainment. The associations are reported without covariate adjustment, both separately for each study and for the combined data set:

1. For cannabis there were clear \((p<0.001)\) trends for increasing frequency of use to be associated with lower educational attainment both separately in each study and in the combined data. In the combined data, those who used cannabis at least weekly prior to age 17 had odds of high school non-completion, university non-enrolment, and degree non-attainment that were between 2.20-3.89 times higher than for those who had never used cannabis.

2. For alcohol there were significant associations between increasing frequency of use and lower educational attainment. However, these associations appeared more modest than those for cannabis, and at the individual study level were not always statistically significant. In the combined data those who used alcohol at least weekly had odds of high school non-completion, university non-enrolment, and degree non-

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8Supplementary material can be found by accessing the online version of this paper at http://dx.doi.org and by entering doi:...
attainment that were between 1.33-2.03 times higher than those who had never used alcohol.

3.2. Adjustment for confounding

Table 3 shows results from analyses using combined data. After adjustment for confounding, all of the associations between frequency of cannabis use and educational non-involvement across levels of exposure remained (p<0.02): weekly cannabis users had adjusted odds of non-involvement that were 1.51-1.96 times higher than for those who had never used cannabis. For alcohol use all of the adjusted associations were non-significant, and in two outcomes were reversed in direction after adjustment: the adjusted odds for weekly users ranged between 0.88-1.21 compared to never users.

The alcohol frequency measure, while technically comparable to the cannabis frequency measure, may not necessarily characterise the range of alcohol use patterns in adolescence. To examine whether a similar pattern of results held for other measures of alcohol use in adolescence, we examined the associations between educational outcomes and measures of the maximum number of (a) standard drinks consumed on a typical drinking occasion, and (b) alcohol-related problems, prior to age 17. This analysis showed little evidence of associations between measures of alcohol use and educational outcomes after adjustment for confounding (Supplementary Material6).

Table 4 shows the attributable risk (AR) for cannabis use and the three measures of alcohol use estimated from the adjusted regression models fitted to the combined data for 9

9Supplementary material can be found by accessing the online version of this paper at http://dx.doi.org and by entering doi:...
each educational outcome. The AR estimate the proportion of educational non-
invornment attributable to cannabis use and alcohol use if causality is assumed. For all
outcomes the AR estimates for cannabis use were greater than those for all measures of
alcohol use: the AR estimates ranged from 4.8% to 7.2% for cannabis and from -3.7% to
6.4% for alcohol.

3.3. Supplementary analysis

Tests for non-linearity were non-significant and the linear model was found to
provide an adequate representation of the data, with one exception: for the association
between frequency of cannabis use and non-enrolment in university there was evidence of
a modest but statistically significant departure from linearity (p=0.03). However, re-analysis
of the association with frequency of cannabis use treated as a categorical variable produced
estimates of effect size and AR that were consistent with those of the linear model.

For one association (frequency of alcohol use and high school non-completion) there
was evidence of significant (p=0.003) between-study heterogeneity in the effect of alcohol.
This appeared to reflect the fact that for the CHDS the adjusted association between
frequency of alcohol use and high school non-completion was stronger than in the
Australian cohorts (ATP, VAHCS) and remained significant after covariate adjustment. For all
other associations there was no evidence of between-study heterogeneity.

We examined how study conclusions may differ if educational attainment was
modelled as a sequential process (e.g., having attained one level of qualification what is the
probability of achieving the next level of attainment) (Supplementary Material 810). The

10Supplementary material can be found by accessing the online version of this paper at
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results show that the effects attenuate slightly when the analysis is restricted to those who have completed high school, but the conclusions are essentially the same. The adjusted effect sizes for cannabis are in the expected direction suggesting adverse effects of increasing use on educational attainment and are statistically significant for degree attainment, whereas the adjusted effects for alcohol are virtually unchanged from the main analysis and non-significant.

4. DISCUSSION

Our findings show clear and consistent associations between the frequency of adolescent cannabis or alcohol use and non-attainment of secondary school and tertiary qualifications. The associations had dose-response characteristics across all outcomes, with effects strongest for weekly users. After controlling for a wide range of potential confounding factors, the magnitude of associations for cannabis use reduced substantially but remained significant. In contrast, for frequency of alcohol use, the adjusted associations with all outcomes were weak and statistically non-significant, and a similar pattern of results generally held for two other measures of alcohol use. Early cannabis use was found to account for a greater proportion of the overall rate of non-progression with formal education than early alcohol use.

Support for a causal link between cannabis use and educational attainment is provided by several aspects of the findings. First, there were strong bivariate associations between adolescent cannabis use and all three educational outcomes. Second, the associations had dose-response characteristics (i.e., more frequent use was associated with
lower educational attainment). Third, all associations remained with control for potential confounding factors assessed before and during adolescence.

The specificity of the adjusted associations for cannabis use across the three educational outcomes also has important implications in terms of the drug’s purported causal effects. Traditional criteria for establishing causality includes specificity of association, yet this criterion is inconsistently fulfilled in research (Macleod et al., 2004). Studies have found cannabis, alcohol and tobacco may show similar associations with some psychosocial outcomes (which does not support a causal relationship; Macleod et al., 2004; Stiby et al., 2015). Our findings are aligned with other studies which show some adverse psychosocial outcomes were more consistently associated with cannabis and others with alcohol (Palamar et al., 2014). Our analyses adjusted for major sources of potential confounding (including adolescent tobacco exposure) and accounted for the comorbidity between cannabis and alcohol use. Results suggest it may be cannabis use specifically, rather than substance use generally (as measured by alcohol consumption), that is associated with non-progression with education. The health and developmental outcomes associated with cannabis or alcohol use may well be different. While alcohol has a critical role in some adverse outcomes, as witnessed by its burden of disease (Rehm et al., 2009), study findings do not support a direct link with educational attainment. The extent to which individual and contextual factors account for the association between adolescent substance use and educational attainment appears greater in relation to early alcohol use than early cannabis use.

Study findings in relation to the association between adolescent cannabis use and lower educational attainment are consistent with previous research (Esch et al., 2014;
Macleod et al., 2004; Maggs et al., 2015; Silins et al., 2014; Townsend et al., 2007). The association between cannabis use and high school non-completion probably does not arise from a reverse causal association (e.g., school drop-out contributing to cannabis use; Fergusson et al., 2003a), however it remains plausible(Townsend et al., 2007). Studies such as ours have limited capacity to explain the underlying mechanisms. Some research suggests that heavy cannabis use in adolescence might affect CNS development as the drug has characteristic neurophysiological effects which vary by pattern of use (Lisdahl et al., 2013). Alternatively, study findings may reflect the different social and cultural contexts of early cannabis or alcohol use. Adolescent cannabis use (arguably less normative than adolescent alcohol use; European Monitoring Centre for Drugs and Drug Addiction, 2014; World Health Organization, 2014) may be a marker for underlying problems or contexts such as peer affiliations or family environments which increase the risk of lower educational attainment(Busch et al., 2014; Verweij et al., 2013). This is an area for future research. Although we controlled for many potential confounding factors, the possibility that the associations with cannabis use might show the effects of unmeasured or uncontrolled confounding can never be completely ruled out (Macleod et al., 2004). However, analyses using fixed-effects regression to control for non-observed confounders suggest that associations between cannabis use and various outcomes remain(Fergusson et al., 2005, 2003b).

The absence of an incremental effect of cannabis use on progressively higher levels of educational achievement suggests that most of the risk for lower educational outcomes beyond high school could be accounted for by influences prior to the completion of secondary school. While the outcomes examined reflect a general dimension of non-
progression with formal education, in the current context of youth unemployment, some who leave school and find secure employment soon after may do better than those who go on to university in terms of transitions to independence in young adulthood (Eisenberg et al., 2015).

This study had some limitations. First, weekly alcohol use in adolescence is more normative than weekly cannabis use and may not necessarily encapsulate high-end use. However, a sensitivity analysis which included frequency of heavier drinking (10+ drinks in a typical session) produced results consistent with the main findings (Supplementary Material91). Second, there was some between-study variation in the levels of outcomes which was greater for alcohol than for cannabis. This could have been shown by variations in estimates of effect size across studies and failure to find a statistically significant association. However, such estimates were very similar, with Wald tests (in adjusted models) providing no evidence of significant between-study heterogeneity except for frequency of alcohol use and failure to complete high school. Further, the estimate of the pooled AR from a model that assumed different regression parameters in each study for the association between alcohol use and high school non-completion was similar to the AR estimate reported in Table 4. Third, we cannot rule out that high school participation may have ended before the onset of cannabis use. Fourth, the adjusted associations for cannabis use and educational outcomes are slightly weaker than those reported in a previous integrated analysis using the same data (Silins et al., 2014), possibly due to the use of a more sophisticated form of covariate control in the current study. Fifth, measures were obtained

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by self-report, which might be subject to socially desirable response bias, the extent of which can vary with age (Brener et al., 2003). Sixth, similarities in the cultural and social context and epidemiology of substance use between Australia, New Zealand, and other high-income countries (UNICEF Office of Research, 2013) suggests findings are generalizable to those settings. Generalizability to lower-income countries where the epidemiology and socio-economic context of cannabis use is not well understood remains to be established.

This study extends previous research on the link between adolescent substance use and non-progression with formal education by integrating data from three sources and controlling for a broader range of covariates than possible in traditional meta-analysis. Weekly adolescent cannabis use had a profound adverse effect across all three educational outcomes. In contrast, much of the association between early alcohol use and educational non-involvement was explained by individual, parental and peer factors. Findings strengthen the case for cannabis' harmful effects on adolescent development and are important to the debate about the relative harms of cannabis and alcohol use. While alcohol has a major role in some adverse outcomes (Rehm et al., 2009), the claim that cannabis use is less harmful than alcohol use (Lachenmeier and Rehm, 2015) is unsupported by results in relation to the critical domain of educational attainment. Study findings show that adolescent cannabis use is a better marker of lower educational attainment than adolescent alcohol use and identifies an important target population for preventive intervention. Addressing adolescent cannabis use provides a means of improving education outcomes with potential economic benefits (Day and Newburger, 2002).
The Cannabis Cohorts Research Consortium

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REFERENCES


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<table>
<thead>
<tr>
<th>Harmonised exposure variable</th>
<th>Constituent measures</th>
<th>ATP</th>
<th>CHDS</th>
<th>VAHCS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maximum frequency of cannabis use prior to age 17</strong> (Never, &lt;weekly, weekly+)</td>
<td>Frequency of use in past month (number of days use) at age 15-16. Less frequent than monthly use not assessed. Such use was defined using the assessment of lifetime cannabis use at age 15-16 and age 13-14.</td>
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<td></td>
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</tr>
<tr>
<td><strong>Maximum frequency of alcohol use prior to age 17</strong> (Never, &lt;weekly, weekly+)</td>
<td>Lifetime use (3+ drinks in lifetime; yes/no) and number of drinking days in past month at age 13 and 15.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Maximum number of standard drinks consumed on a single drinking occasion prior to age 17</strong> (0-2, 3-6, 7-12, 13+)</td>
<td>Number of drinks consumed not assessed.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Frequency of use in each of the 12 month periods from age 14-15, 15-16, 16-17 years, obtained from assessments conducted at ages 15, 16, 18 years respectively (classified as: not used, once or twice, less than once a month, at least once a month, at least once a week, nearly every day).</td>
<td></td>
<td></td>
<td>Frequency of use in past 6 months assessed at each of 6 biannual assessments between ages 15-17½ years, on average (response categories: never, not in past 6 months, a few times a year, monthly, weekly, daily).</td>
</tr>
<tr>
<td></td>
<td>Current drinking status (non-drinker, light, moderate, heavy) and number of drinking days in the past week were assessed using a 7-day retrospective drinking diary at each of 6 biannual assessments between ages 15-17½. Average number of standard drink units (10 grams of alcohol) consumed per drinking day in the past week at 6 biannual assessments between ages 15-17½.</td>
<td></td>
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<tr>
<td></td>
<td>Amount of alcohol consumed (in millilitres of pure alcohol) on a typical drinking occasion at ages 14, 15, and 16.</td>
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<td></td>
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</tr>
<tr>
<td>Maximum number of alcohol-related problems prior to age 17</td>
<td>Frequency of 5 drinking-related problems over the lifetime at age 15.</td>
<td>Number of alcohol abuse/dependence symptoms (Rutgers Alcohol Problems Index(^2)) in the past 12 months at age 15 and 16 (23 items).</td>
<td>Number of drinking-related problems (13 items) in past 6 months at 6 biannual assessments between ages 15-17½.</td>
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</tbody>
</table>

ATP=Australian Temperament Project. CHDS=Christchurch Health and Development Study. VAHCS=Victorian Adolescent Health Cohort Study. 
\(^1\)Maximum value based on multiple assessments in adolescence. \(^2\)White and Labouvie, 1989.
Table 2. Associations between maximum frequency of cannabis or alcohol use before age 17 and educational outcomes in each study and when the data were combined

<table>
<thead>
<tr>
<th>Measure</th>
<th>Frequency of substance use</th>
<th>p value&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>&lt;Weekly</td>
<td>Weekly +</td>
</tr>
<tr>
<td><strong>Outcome: Did not complete high school</strong>&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cannabis use</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATP</td>
<td>64/897 (7%)</td>
<td>26/202 (13%)</td>
</tr>
<tr>
<td>CHDS</td>
<td>311/618 (50%)</td>
<td>215/339 (63%)</td>
</tr>
<tr>
<td>VAHCS</td>
<td>126/977 (13%)</td>
<td>69/372 (19%)</td>
</tr>
<tr>
<td>Combined data</td>
<td>501/2492 (20%)</td>
<td>310/913 (34%)</td>
</tr>
<tr>
<td>OR (95% CI)</td>
<td>1</td>
<td>1.82</td>
</tr>
<tr>
<td><strong>Alcohol use</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATP</td>
<td>21/270 (8%)</td>
<td>46/581 (8%)</td>
</tr>
<tr>
<td>CHDS</td>
<td>45/103 (44%)</td>
<td>386/699 (55%)</td>
</tr>
<tr>
<td>VAHCS</td>
<td>40/365 (11%)</td>
<td>75/392 (19%)</td>
</tr>
<tr>
<td>Combined data</td>
<td>106/738 (14%)</td>
<td>507/1672 (30%)</td>
</tr>
<tr>
<td>OR (95% CI)</td>
<td>1</td>
<td>1.42</td>
</tr>
<tr>
<td><strong>Outcome: Did not enrol in university</strong>&lt;sup&gt;3,4&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cannabis use</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHDS</td>
<td>362/596 (61%)</td>
<td>222/329 (67%)</td>
</tr>
<tr>
<td>VAHCS</td>
<td>373/978 (38%)</td>
<td>153/373 (41%)</td>
</tr>
<tr>
<td>Combined data</td>
<td>735/1574 (47%)</td>
<td>375/702 (53%)</td>
</tr>
<tr>
<td>OR (95% CI)</td>
<td>1</td>
<td>1.48</td>
</tr>
<tr>
<td><strong>Alcohol use</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CHDS</td>
<td>VAHCS</td>
</tr>
<tr>
<td>--------</td>
<td>------------</td>
<td>------------</td>
</tr>
<tr>
<td></td>
<td>62/102 (61%)</td>
<td>434/673 (64%)</td>
</tr>
<tr>
<td></td>
<td>133/366 (36%)</td>
<td>167/392 (43%)</td>
</tr>
<tr>
<td></td>
<td>195/468 (42%)</td>
<td>601/1065 (56%)</td>
</tr>
<tr>
<td>OR (95% CI)</td>
<td>1</td>
<td>1.15</td>
</tr>
<tr>
<td></td>
<td>(1.03-1.29)</td>
<td>(1.06-1.66)</td>
</tr>
</tbody>
</table>

**Outcome: Did not attain university degree**

**Cannabis use**

<table>
<thead>
<tr>
<th></th>
<th>ATP</th>
<th>CHDS</th>
<th>VAHCS</th>
<th>Combined data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>375/734 (51%)</td>
<td>415/596 (70%)</td>
<td>563/978 (58%)</td>
<td>1353/2308 (59%)</td>
</tr>
<tr>
<td></td>
<td>111/156 (71%)</td>
<td>252/320 (79%)</td>
<td>261/373 (70%)</td>
<td>624/849 (74%)</td>
</tr>
<tr>
<td></td>
<td>22/30 (73%)</td>
<td>76/81 (94%)</td>
<td>128/147 (87%)</td>
<td>226/258 (88%)</td>
</tr>
<tr>
<td>OR (95% CI)</td>
<td>1</td>
<td>1.97</td>
<td>3.89</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>(1.73-2.25)</td>
<td>(2.98-5.08)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Alcohol use**

<table>
<thead>
<tr>
<th></th>
<th>ATP</th>
<th>CHDS</th>
<th>VAHCS</th>
<th>Combined data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>122/222 (55%)</td>
<td>74/102 (73%)</td>
<td>210/366 (57%)</td>
<td>406/690 (59%)</td>
</tr>
<tr>
<td></td>
<td>257/472 (54%)</td>
<td>483/666 (73%)</td>
<td>238/392 (61%)</td>
<td>978/1530 (64%)</td>
</tr>
<tr>
<td></td>
<td>118/194 (61%)</td>
<td>133/157 (85%)</td>
<td>516/755 (68%)</td>
<td>767/1106 (69%)</td>
</tr>
<tr>
<td>OR (95% CI)</td>
<td>1</td>
<td>1.25</td>
<td>1.57</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>(1.14-1.39)</td>
<td>(1.29-1.92)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data are n/N (%). ATP=Australian Temperament Project. CHDS=Christchurch Health and Development Study. VAHCS=Victorian Adolescent Health Cohort Study. ¹P value of the association between adolescent alcohol use and each outcome in each study, and in combined data adjusted for study-specific effects. ²Assessed at age 25 years. ³Assessed at age 21 years. ⁴Only CHDS and VAHCS assessed university enrolment.
Table 3. Associations (ORs, 95% CI) between maximum frequency of cannabis or alcohol use before age 17 and educational outcomes in combined data after adjustment\textsuperscript{4} for confounding

<table>
<thead>
<tr>
<th>Measure</th>
<th>Frequency of substance use</th>
<th>Never</th>
<th>&lt;Weekly</th>
<th>Weekly +</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outcome: Did not complete high school\textsuperscript{1}</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cannabis use</td>
<td></td>
<td>1</td>
<td>1.27 (1.05-1.53)</td>
<td>1.60 (1.09-2.35)</td>
<td>0.016</td>
</tr>
<tr>
<td>Alcohol use</td>
<td></td>
<td>1</td>
<td>1.10 (0.91-1.34)</td>
<td>1.21 (0.83-1.78)</td>
<td>0.323</td>
</tr>
<tr>
<td><strong>Outcome: Did not enrol in university\textsuperscript{2,3}</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cannabis use</td>
<td></td>
<td>1</td>
<td>1.23 (1.03-1.46)</td>
<td>1.51 (1.06-2.13)</td>
<td>0.021</td>
</tr>
<tr>
<td>Alcohol use</td>
<td></td>
<td>1</td>
<td>0.94 (0.80-1.10)</td>
<td>0.88 (0.64-1.21)</td>
<td>0.420</td>
</tr>
<tr>
<td><strong>Outcome: Did not attain university degree\textsuperscript{1}</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cannabis use</td>
<td></td>
<td>1</td>
<td>1.40 (1.17-1.68)</td>
<td>1.96 (1.36-2.81)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Alcohol use</td>
<td></td>
<td>1</td>
<td>0.95 (0.83-1.09)</td>
<td>0.90 (0.68-1.18)</td>
<td>0.470</td>
</tr>
</tbody>
</table>

Data are odds ratios (95% CIs).\textsuperscript{1} Assessed at age 25 years. \textsuperscript{2} Assessed at age 21 years. \textsuperscript{3} Only CHDS and VAHCS assessed university enrolment. \textsuperscript{4} Adjusted using a multiple propensity score approach, with propensity scores computed for each individual based on the available likely predictors of adolescent cannabis or alcohol use and combined across studies (ATP: school problems, 14-15 years; conduct disorder 13-16 years; attentional problems, 13-16 years; tobacco use, 13-16 years; other illicit drug use before 17 years; depression, 13-16 years; sex; ethnicity; parental socio-economic status; parental alcohol and tobacco use; parental education; parental divorce; antisocial peer activities, 13-16 years. CHDS: Grade point average, 11-13 years; conduct problems, 7-9 years; attentional problems, 7-9 years; tobacco use, 10-15 years; other illicit drug use before 17 years; major depression, 14-16 years; sex; ethnicity; socio-economic status at birth; family living standards, 1-10 years; parental history of criminal offending, parental tobacco use; parental history of alcohol problems; parental illicit drug use; parental history of mental health problems; parental education level at birth, parental separation, 0-10 years; deviant peer affiliations, 15 years. VAHCS: antisocial behaviour before 17 years; tobacco use before 17 years; other illicit drug use before 17 years; symptoms of depression/anxiety before 17 years; sex; ethnicity; parental tobacco use; parental alcohol use; parental education; parental divorce/separation; peer alcohol use before 17 years; peer tobacco use before 17 years; peer other illicit drug use before 17 years; peer conduct problems before 17 years; peer attention problems before 17 years; peer tobacco use before 17 years; peer other illicit drug use before 17 years; peer family living standards, 1-10 years; peer antisocial behaviour before 17 years; peer conduct problems, 7-9 years; peer attentional problems, 7-9 years; peer tobacco use, 10-15 years; peer other illicit drug use before 17 years; peer major depression, 14-16 years; peer sex; peer ethnicity; peer socio-economic status at birth; peer family living standards, 1-10 years; peer parental history of criminal offending, peer parental tobacco use; peer parental history of alcohol problems; peer parental illicit drug use; peer parental history of mental health problems; peer parental education level at birth, peer parental separation, 0-10 years; peer deviant peer affiliations, 15 years.


years). Propensity score models included alcohol use before age 17 as a predictor of cannabis use and cannabis use before age 17 as a predictor of alcohol use in all studies.
Table 4. Estimates of attributable risk (AR) for measures of cannabis or alcohol use before age 17 on educational outcomes after adjustment for confounding

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Cannabis (Max frequency)</th>
<th>Alcohol (Max frequency)</th>
<th>Alcohol (Max amount drunk)</th>
<th>Alcohol (Alcohol-related problems)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not complete high school</td>
<td>7.2%</td>
<td>6.4%</td>
<td>0.8%</td>
<td>5.2%</td>
</tr>
<tr>
<td>Did not enrol in university</td>
<td>4.8%</td>
<td>-3.7%</td>
<td>1.6%</td>
<td>-0.8%</td>
</tr>
<tr>
<td>Did not attain university degree</td>
<td>5.0%</td>
<td>-2.0%</td>
<td>1.4%</td>
<td>0.2%</td>
</tr>
</tbody>
</table>

1Assessed at age 25 years. 2Assessed at age 21 years. 3Only CHDS and VAHCS assessed university enrolment. 4Only CHDS and VAHCS assessed quantity of alcohol drunk. 5Adjusted using a multiple propensity score approach, with propensity scores computed for each individual based on the available likely predictors of adolescent cannabis or alcohol use and combined across studies (see Table 2 for specific predictors included).
Contributors

This paper was conceptualized and designed by DMF, GCP, RPM and LJH. Data were acquired by LJH, DMF, GCP, JWT, CAO and CC. Data analysis was conducted by ES and LJH. All authors contributed to data interpretation. ES, LJH and RJT drafted sections of the paper. All authors revised the paper critically and approved the version published.
Conflict of interest

None declared.
Role of the funding source

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Acknowledgement

We thank all individuals and families involved in the participating cohorts for their time and invaluable contribution to the study; all collaborators who have contributed to the Australian Temperament Project, especially Ann Sanson, Diana Smart, Margot Prior, and Frank Oberklaid; and Christina O’Loughlin, John Carlin, and Helen Romaniuk for their contributions to the Victorian Adolescent Health Cohort.
Adolescent cannabis use increased the odds of non-progression with formal education.

Associations for adolescent alcohol use were inconsistent and weaker.

Cannabis use accounted for a greater proportion of the overall rate of educational underachievement than alcohol use.

Findings inform the debate about the relative harms of cannabis and alcohol use.