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Drinking, smoking, and educational achievement: Cross-lagged associations from adolescence to adulthood

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Abstract

Background—Adolescent substance use is associated with lower educational achievement but the directionality of the association remains uncertain. We analyzed data on drinking, smoking and educational achievement to study the associations between substance use and education from early adolescence to young adulthood.

Methods—Longitudinal data from four time points (ages 12, 14, 17, and 19-27 years) from a population-based cohort study of Finnish twin individuals were used to estimate bivariate cross-lagged path models for substance use and educational achievement, adjusting for sex, parental covariates, and adolescent externalizing behavior. A total of 4,761 individuals (49.4% females) were included in the analyses. Educational achievement was assessed with teacher-reported grade point average at ages 12 and 14, and with self-reported student status and completed education at age 17 and in young adulthood. From self-reported questionnaire items, frequency of any drinking, frequency of drinking to intoxication, any smoking and daily smoking were analyzed.

Results—Alcohol use and smoking behaviors at ages 12 and 14 predicted lower educational achievement at later time points even after previous achievement and confounding factors were taken into account. Lower school achievement in adolescence predicted a higher likelihood of

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Contributors

AL and JK designed the study. JK, RJR, and LP collected the FT12 data. AL conducted the statistical analysis and wrote the first draft of the manuscript. JK, RJR, TK, DMD and LP provided feedback and contributed to subsequent versions of the manuscript. All authors contributed to and have approved the final manuscript.

Author disclosures:

Conflict of Interest

Dr. Latvala was a co-author in a review project on underage drinking, funded by ERAB: The European Foundation for Alcohol Research, in 2011-2012. Dr. Korhonen has served as a consultant to Pfizer in 2011 and 2012 on tobacco dependence. Dr. Kaprio has consulted for Pfizer on nicotine dependence in 2011 and 2012, and for ERAB on alcohol drinking in 2011. Other co-authors declare no conflicts of interest.

engaging in smoking behaviors but did not predict later alcohol use. Higher educational attainment at age 17 predicted more frequent drinking in young adulthood.

Conclusions—Adolescent drinking behaviors are associated with lower future educational achievement independently of prior achievement, whereas smoking both predicts and is predicted by lower achievement. Early substance use indexes elevated risk for poor educational outcomes.

Keywords

adolescent; alcohol use; smoking; educational achievement; cross-lagged model; longitudinal

1. INTRODUCTION

Disorders and problems related to substance use are more prevalent among people with low education (Jacobi et al., 2004; Kessler et al., 2005; Latvala et al., 2009; Leach and Butterworth, 2012). However, the association between educational level and substance use is not straightforward. For example, in many countries abstaining from alcohol is less common and non-problematic alcohol use more frequent among people with high education (Casswell et al., 2003; Helakorpi et al., 2012; Helasoja et al., 2007; Patrick et al., 2012). Smoking behaviors currently exhibit a strong socioeconomic gradient in many countries such that those with higher education are much less likely to smoke (Helakorpi et al., 2008; Hiscock et al., 2012).

Substance use and educational outcomes become associated during adolescence (Townsend et al., 2007) but reasons for the association remain poorly understood. Theoretically, the association could be due to several mechanisms (see, e.g., Haller et al., 2010) which can be either causal or non-causal. First, there could be a causal influence of the educational domain on substance use. Thus, difficulties and poor performance in school might, via mediating psychological and social factors, causally lead to increased substance use. Alternatively, the causal relationship could run in the opposite direction so that substance use would influence educational outcomes. Such an adverse effect could be related to, e.g., cognitive or motivational factors influencing school performance, or substance use could foster contact with peer groups unfavorable for school achievement. Third, the causal relationship could be reciprocal, whereby poor school outcomes and substance use behaviors would mutually influence each other and lead to a self-reinforcing process. Finally, the association could be non-causal and merely reflect confounding factors influencing both educational and substance use outcomes. For example, familial background may be related both to education and substance use and could create a spurious association between the two (Patrick et al., 2012; Melotti et al., 2011). Similarly, externalizing behavior problems in adolescence could confound the association (Breslau et al., 2009).

Several longitudinal studies have been conducted with results suggesting both that early substance use predicts poor school achievement and that academic failure is predictive of substance use (Ellickson et al., 2001; Hayatbakhsh et al., 2011; King et al., 2006; Pitkänen et al., 2008). More informative than studies that simply test the association in one direction are longitudinal analyses which test the predictive associations simultaneously in both directions while adjusting for the developmental stability of academic and substance use behaviors (Beal and Crockett, 2010; Maggs and Schulenberg, 2005).Cross-lagged path analysis of longitudinal data allows this by modeling autoregressive and cross-lagged associations simultaneously, but such analyses are rare in the literature, and even rarer are studies involving more than two time points.

Existing cross-lagged analyses of educational achievement and drinking or smoking behaviors have been methodologically variable and have produced differing results. Thus,

among nearly 12,000 middle and high school students from the National Longitudinal Study of Adolescent Health, academic failure predicted alcohol use (but not binge drinking) one year later, but only a suggestive effect of alcohol use on academic failure was noted (Crosnoe, 2006). In contrast, a much smaller study of 405 participants in a high-risk sample found no cross-lagged associations between academic achievement and binge drinking across three study waves spanning an 18-year period (Haller et al., 2010). Bidirectional cross-lagged associations between school achievement and smoking across adolescence were indicated in two large studies (Pennanen et al., 2011; Tucker et al., 2008). In contrast, in data from the Monitoring the Future project academic achievement negatively predicted smoking from 8th to 12th grade but the reverse was not found (Bryant et al., 2000).

Clearly, more longitudinal analyses across multiple assessments through adolescence are required to capture the developmental interconnections between educational achievement and substance use. In addition, investigating different measures of substance use behaviors in the same sample would be informative as educational achievement could be differentially related to the use of different substances (e.g., alcohol vs. tobacco), and the nature of substance use (e.g., any drinking vs. drinking to intoxication).

We conducted cross-lagged path analyses on four waves of data from age 12 to young adulthood in a population-based sample of Finnish twins. Our aim was to investigate the directionality and magnitude of associations between educational achievement and drinking and smoking behaviors across adolescence and young adulthood. In order to remove potential confounding by externalizing behaviors, analyses adjusting for behavior problems in adolescence were also conducted. Based on previous findings, we hypothesized that the associations of educational achievement with drinking and smoking behaviors would be bidirectional. Further, we hypothesized that stronger associations would be found for more severe (i.e., drinking to intoxication, daily smoking) than for less severe (i.e., any drinking, any smoking) substance use behaviors. Theory and previous findings did not permit clear hypotheses concerning the relative strength of the associations with drinking and smoking behaviors.

2. METHODS

2.1 Participants

FinnTwin12 (FT12) is a longitudinal study of five consecutive birth cohorts (1983-1987) of Finnish twins and their families (Kaprio et al., 2002). Families with twins were identified via Finland's Population Register Centre and contacted when the twins were 11-12 years. After baseline data collection (N = 2,724 families, response rate 87%), the sample has been followed up with questionnaire surveys at ages 14 years, 17.5 years, and as young adults at an average age of 24 years (SD = 1.7, range 19-27), with consistently high response rates (85-90% at each wave of data collection; Kaprio et al., 2002; Kaprio, 2006). The study protocol was approved by the Ethical Committee of the University of Helsinki and the IRB of Indiana University. Parents provided written informed consent for their and their children's participation. At baseline, parents also reported on their own socioeconomic and health characteristics, including education, alcohol use and smoking.

All available data from the four study waves of FT12 were used. In total, some data were available for 5,293 twin individuals (2,625 or 49.6% females). The number of observations varied for each study wave and variable, ranging between 1,869 and 4,709 (Table 1). The smaller number for age 12 alcohol and smoking variables was because that information was available only from an intensively studied sub-sample. Namely, nested within the full population-representative FT12 study is a more intensively studied sub-sample of 2,070 twin

individuals who were asked to complete an in-school questionnaire at age 12, including items on alcohol use and smoking (Kaprio et al., 2002).

School performance at ages 12 and 14 was reported by the twins' teachers (see below) as part of a behavioral assessment. The teachers' reports were associated with some missing data at age 14, because many twins were unable or unwilling to nominate a teacher who knew them well. In contrast, at age 12, the twins had a single main teacher who was contacted with parental permission. Parental covariates (see below) were not available for 532 twin individuals from 274 families. Accordingly, path models adjusting for parental factors were based on a total of 4,761 individuals (2,354 or 49.4% females).

2.2 Measures

2.2.1 Educational achievement—In the Finnish educational system, compulsory education continues through grade nine (age 16). Secondary education is divided into vocational and academic secondary education (high-school), lasting typically two and three years, respectively. Tertiary education is provided by universities and polytechnics. In order to enter tertiary education, high-school is generally required.

Assessment of educational achievement was based on teacher-reported school performance at the first two study waves and on self-reported information on ongoing and completed education at the last two waves. Specifically, when the twins were 12 and 14 years their teachers responded to questionnaire items on school performance, including grade point average (GPA) in the latest report. Finnish schools use a uniform grading system of 7 numbered grades (4 to 10, from failure to highest). Five ordered categories for GPA were used in the teachers' questionnaire: (1) 9.0 or over, (2) 8.0 – 8.9, (3) 7.0 – 7.9, (4) 6.0 – 6.9, and (5) Below 6. For analyses, this scale was reversed so that higher values denoted better performance.

At age 17, the twins reported on their current student status. Responses were classified into an ordinal variable with three categories: (0) Not studying currently, (1) In vocational training, (2) In high-school. In young adulthood, educational attainment was based on a questionnaire item on the highest level of completed education, ranging from compulsory schooling to tertiary education. In addition, for those twins who had not yet completed their education, ongoing studies were treated as the final, expected education. Educational attainment in young adulthood was coded into four ordered categories: (0) Compulsory education only, (1) Vocational secondary education, (2) Academic secondary education, and (3) Tertiary education.

2.2.2 Drinking—Alcohol use behaviors employed in our analyses were the frequency of drinking any alcohol and the frequency of drinking to intoxication. This information was based on questionnaire items at each study wave. The item on intoxication was not included in the age 12 questionnaire. At age 12, the dichotomous drinking variable asked "Have you ever drunk alcohol without adults around". "No" responses were coded as 0 and "Yes" responses as 1. At ages 14 and 17, the frequency variables for any drinking and drinking to intoxication had the following four ordered categories: (0) I do not use alcohol, (1) Less than once a month, (2) Approximately once or twice a month, and (3) Once a week or more often. In young adulthood, the variable for drinking to intoxication had these same four categories, while the categorization of the frequency of any drinking was: (0) Less than once a month or never, (1) Approximately once or twice a month, (2) Once a week, and (3) A couple of times a week or more often. These variables have been used in earlier analyses of drinking behaviors in the Finnish twin cohort data (Dick et al., 2011; Latvala et al., in press; Pagan et al., 2006; Rose et al., 1999; Viken et al., 1999).

2.2.3 Smoking—At age 12, a dichotomous variable on having ever tried smoking was used; with "Yes" responses coded as 1 and "No" responses as 0. Based on several questions on smoking initiation and current smoking habits, any current smoking and current daily smoking at ages 14, 17 and in young adulthood were studied. These smoking behaviors were indexed by two dichotomous variables, one for any current smoking and one for daily smoking, for which "Yes" responses were coded as 1 and "No" responses as 0.

2.2.4 Covariates—The cross-lagged path analysis adjusted for sex. In addition, to diminish potential confounding by familial factors, parental education, smoking and alcohol use were used as covariates in all models. Parental education was assessed for mothers and fathers as an ordinal variable with four categories, ranging from compulsory schooling only to tertiary education, and the highest education of either parent was used as a covariate. Similarly, alcohol use frequency was assessed separately for mothers and fathers as an ordinal variable, ranging from never use to a few times a week or more often, and the highest frequency of parental drinking was used. Parental smoking denoted whether either of the parents reported any current smoking at study baseline. In addition to the parental covariates, externalizing behavior problems at age 12 were adjusted for in further analyses. Externalizing behaviors were rated by the twins' teachers using a Finnish scale, the Multidimensional Peer Nomination Inventory (MPNI), which has sub-scales for hyperactivity-impulsivity, aggression, and inattention (Pulkkinen et al., 1999). A sum score of these sub-scales, previously shown to predict substance use (Korhonen et al., 2010, 2012), was used to assess externalizing behavior problems.

2.3 Statistical analysis

The twins were treated as individuals by adjusting standard errors for the clustering of observations in twin pairs using the *type=complex* specification and the cluster option implemented in Mplus 5.2 (Muthén and Muthén, 2007). This option uses the pseudomaximum likelihood method in which the asymptotic covariance matrix of the estimates is obtained by a robust sandwich estimator (Asparouhov, 2005). Bivariate cross-lagged path models were fitted separately for each substance use variable (any drinking, drinking to intoxication, smoking, and daily smoking) with educational achievement across the four study waves, adjusting for covariates. Besides autoregressive and cross-lagged paths between successive time points, the models included additional autoregressive paths on variables at waves 3 and 4 from the equivalent measures two waves earlier (e.g., a path from drinking frequency at age 14 to drinking frequency in young adulthood). Such paths may be used to improve model fit in models with three or more measurements (Tucker et al., 2013). Residual correlations at each wave were also modeled in order to account for the remaining cross-sectional correlation between educational achievement and substance use, unexplained by the cross-lagged associations. The full estimated model is presented as a path diagram in Figure 1.

Weighted least squares estimation for ordinal outcome variables in Mplus was used (Muthén and Muthén, 2007). This estimator allows missing data as a function of the observed covariates. Specifically, data are assumed to be missing at random with respect to the outcome variables but missingness is allowed to be dependent on the covariates. When there are no covariates in the model, this is analogous to pairwise present analysis in which all available data are used to estimate each pairwise association. The weighted least squares estimation has been shown to be consistent and more efficient than estimators based on listwise deletion (Asparouhov and Muthén, 2010). Chi-square tests of model fit were computed taking into account the non-independence of observations due to cluster sampling. Other indicators of model fit were the Root Mean Square Error of Approximation (RMSEA), for which values below .05 are generally taken to indicate good fit, and the

Comparative Fit Index (CFI), for which values greater than .90 are taken to indicate reasonably good fit to data (Kline, 2005).

3. RESULTS

3.1 Correlations between education and substance use variables

Descriptive statistics and bivariate polychoric correlations for educational and substance use variables are given in Table 1. Across age, school performance and education variables were strongly positively associated, with polychoric correlations ranging from .6 to .8 ($p<.001$). Associations between alcohol use variables were more variable, with polychoric correlations mostly in the range of .2 ($p<.01$) to .5 ($p<.001$). Smoking variables were consistently positively correlated, with polychoric correlations between .4 and .8 ($p<.001$). In most cases, educational achievement was inversely associated with alcohol use and smoking, with polychoric correlations typically ranging between −.2 and −.4 ($p<.001$). These correlations were stronger for smoking behaviors than for any drinking or drinking to intoxication.

3.2 Cross-lagged models of educational achievement and alcohol use

Modeling results for the frequency of any drinking and drinking to intoxication are presented in Figures 2 and 3, respectively. In these models, significant stability of educational attainment and drinking behaviors across adolescence was observed. The cross-lagged effects indicated that drinking without adults at age 12 predicted lower school performance at age 14, and the frequency of any drinking and drinking to intoxication at age 14 negatively predicted student status at age 17. In contrast, school performance at ages 12 and 14 did not predict later drinking behaviors. Student status at age 17 positively predicted the frequency of any drinking and drinking to intoxication in young adulthood. The models had an excellent fit to the data (drinking: $\chi^2[7]=4.52$, $p=.718$, CFI=1.000, RMSEA=.000; intoxicating: $\chi^2[7]=6.74$, $p=.456$, CFI=1.000, RMSEA=.000).

3.3 Cross-lagged models of educational achievement and smoking behaviors

Models for any current smoking and daily smoking are presented in Figures 4 and 5, respectively. Strong stability of smoking behaviors across age was observed. Having ever smoked by age 12 predicted lower school performance at age 14, and both any current smoking and daily smoking at age 14 negatively predicted student status at age 17. Better school performance at age 14 and higher student status at age 17 decreased the likelihood of smoking at age 17 and in young adulthood, respectively, and better school performance at age 12 decreased the likelihood of smoking daily at age 14. Daily smoking at age 17 also predicted lower education in young adulthood. Similar to alcohol use, the models for smoking behaviors had an excellent fit to data (smoking: $\chi^2[7]=5.95$, $p=.546$, CFI=1.000, RMSEA=.000; daily smoking: $\chi^2[7]=7.03$, $p=.426$, CFI=1.000, RMSEA=.001).

3.4 Cross-lagged models adjusting for adolescent externalizing behaviors

Further analyses were conducted to adjust for potential confounding by adolescent behavior problems. Paths from the teacher-rated externalizing behavior score at age 12 to school performance and substance use variables at ages 12 and 14 were included in these models. For the drinking variables, this adjustment had only minor effects on the cross-lagged path coefficients and did not affect the overall results. In the models for smoking behaviors, the path from school performance at age 12 to daily smoking at age 14 was non-significant after the adjustment (standardized coefficient = −.08, p = .117), and similarly the path from student status at age 17 to any smoking in young adulthood was no longer significant after the adjustment (standardized coefficient = −.04, p = .129). The adjustment also reduced the residual correlations between school performance and substance use at ages 12 and 14 to

non-significance with the exception of school performance and daily smoking at 14. The adjusted models had good fit to data (CFI=.997–1.000, RMSEA=.009–.024, full results available by request).

4. DISCUSSION

In a nationwide sample of twins, we investigated the longitudinal associations of alcohol use and smoking behaviors with educational achievement from adolescence to young adulthood. Cross-lagged path models were fitted to four waves of data, collected at ages 12, 14, and 17.5 years, and in young adulthood. The cross-lagged models allowed a test of directionality of the associations across development. Four main findings are discussed.

First, significant stability of educational achievement, alcohol use and smoking behaviors across age was observed. This finding is consistent with previous studies (Beal and Crockett, 2010; Maggs and Schulenberg, 2005) and it underscores the importance of adjusting for autoregressive effects when studying the complex associations between education and substance use.

Second, the cross-lagged models revealed a consistent pattern in which alcohol use and smoking behaviors at ages 12 and 14 predicted lower educational achievement at later time points even when previous achievement and potential confounding by parental factors and adolescent behavior problems were adjusted for. However, although lower school achievement predicted a higher likelihood of engaging in smoking behaviors it did not predict later alcohol use. Thus, our findings suggest that for any drinking and drinking to intoxication in adolescence, the direction of the association runs from more frequent alcohol use to lower educational achievement, whereas bidirectional associations for smoking behaviors and education were suggested.

Our results provide more consistent evidence than previous cross-lagged analyses on the predictive negative association of early drinking behaviors on later academic achievement. Crosnoe (2006) used a large and representative sample and found that academic failure predicted alcohol use in adolescence more strongly than vice versa, thus contrasting our findings. Several differences between the two studies could explain the discrepancy. Crosnoe (2006) used the number of classes failed as an indicator of academic failure whereas we studied teacher-reported GPA and the level of ongoing or attained education. While these measures are correlated, GPA is likely to capture more variation in school performance than the academic failure index. Naturally, differences in the educational systems and in the general drinking culture between Finland and the U.S. may also explain the findings. Specifically, adolescent alcohol use may be regarded as more deviant in the U.S., whereas experimenting with alcohol is relatively common and even socially normative among Finnish adolescents (Currie et al., 2012).

With regard to smoking, our findings of bidirectional associations with educational achievement replicate previous research (Pennanen et al., 2011; Tucker et al., 2008). Whereas earlier studies have not extended their prediction of educational attainment into young adulthood, we found daily smoking at age 17 predicted lower education in young adulthood, when tertiary education is undertaken. Adjusting for adolescent behavior problems, however, reduced this path to non-significance. Interestingly, our findings for any current smoking and daily smoking were partly different. This suggests that experimental or infrequent smoking is differently associated with educational achievement than is regular and frequent, such as daily, smoking.

As a third finding, the cross-lagged models indicated that student status at age 17 positively predicted any drinking and drinking to intoxication in young adulthood. Thus, adolescents

who are more likely to reach a higher educational level increase their alcohol use as young adults more than do those who truncate their education at a lower level. That might be explained by a transient "college effect" where studying young adults drink more than their non-studying peers (O'Malley and Johnston, 2002). Alternatively, it may reflect a more permanent effect in which the association between education and alcohol use reverses in young adulthood from negative to positive (Crosnoe and Riegle-Crumb, 2007). Compatible with the latter explanation, Finnish adults with higher education tend to drink more often and abstain less than those with lower education, although they have a lower rate of alcohol use disorders (Helakorpi et al., 2012; Helasoja et al., 2007; Latvala et al., 2009). Interestingly, student status at age 17 also appeared to predict the frequency of any drinking stronger than the frequency of drinking to intoxication.

Fourth, the observed cross-lagged associations were often modest and did not fully explain the corresponding cross-sectional correlations. This implies that in addition to earlier substance use and educational achievement, other, unobserved, factors contributed to their association. This is not an unexpected finding, especially because the study waves in FT12 were at least two years apart. However, the cross-lagged effects between smoking and educational achievement we report are of similar magnitude as those reported in an earlier Finnish study with biannual assessments in adolescence (Pennanen et al., 2011).

These findings should be interpreted in context of some limitations. As in all longitudinal studies, there were missing data across study waves and measures. The model estimation method assumed missingness as a function of the covariates but not the outcome variables. This assumption may have been too strict. However, we also conducted the modeling using only the smaller, intensively studied sub-sample which had less missing data, and found a similar pattern of results (available by request).

Second, the measurements of educational attainment and substance use behaviors were not identical across study waves. However, the consistent predictive associations within education and substance use domains across age suggest the results were not significantly influenced by the non-identical content of the variables. Further, it may not be feasible to reliably measure educational achievement and substance use with uniform measures across the studied age period.

Third, while the models adjusted for parental education, drinking, and smoking, as well as adolescent externalizing behaviors, unmeasured residual confounding may still have remained. However, measuring and adjusting for all potential confounders in any single study is very difficult. Further, over-adjustment can also result in problems by obscuring a true effect or creating an apparent effect when none exists (Breslow, 1982).

Finally, although our sample was representative of the Finnish population, the findings may not be fully generalizable to other populations. The Finnish educational system is among the most equal ones globally with very modest between-school variation among Finnish students (Organisation for Economic Cooperation and Development, 2007). Alcohol use and smoking are also relatively common in Finnish adolescents from all socioeconomic backgrounds (Currie et al., 2012). The present study thus clearly extends previous research which is almost entirely based on samples from the United States.

Strengths of the study include the use of a large, population-based sample with data on educational achievement and substance use on four time points from early adolescence to young adulthood. The cross-lagged modeling allowed us to test the directionality of the associations while adjusting for autoregressive effects by simultaneously including educational and substance use variables as both predictors and outcomes. Standardized and uniform teacher-reported grade point averages were available in our sample, improving the

validity of the educational achievement measures in adolescence. The teacher-reported measures were highly predictive of student status and educational attainment later in life.

In conclusion, our findings suggest that early drinking behaviors predict lower academic achievement whereas lower achievement does not predict more frequent drinking when earlier drinking is taken into account. For smoking behaviors, bidirectional negative cross-lagged associations may exist, with smoking and lower educational achievement mutually predicting each other. Even though causality and the mechanisms underlying these directional associations are unknown, early substance use in adolescence should be regarded as an indicator of risk for poor educational outcomes.

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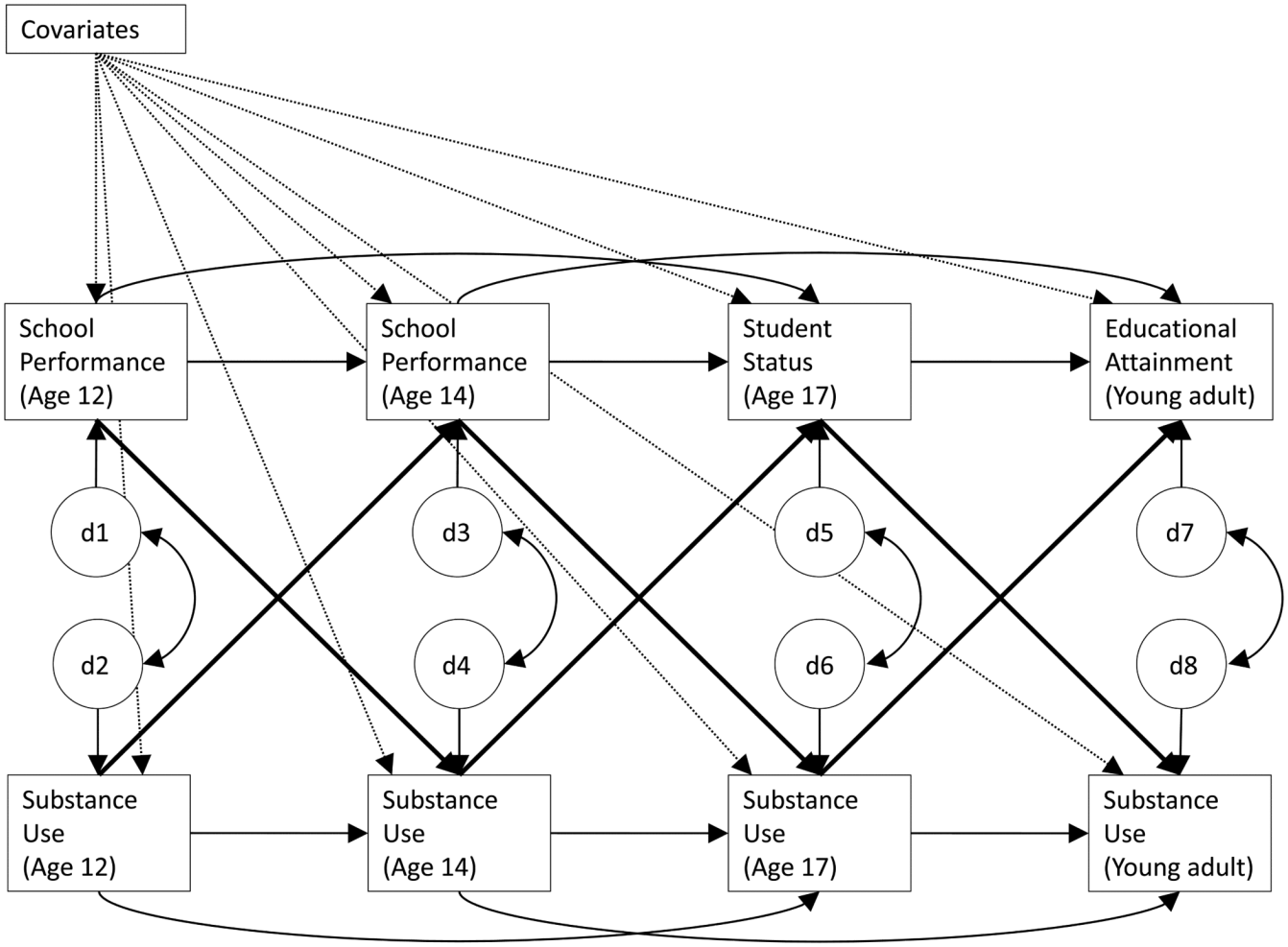

Figure 1.
Full cross-lagged path model for educational achievement and substance use. d, residual variance.

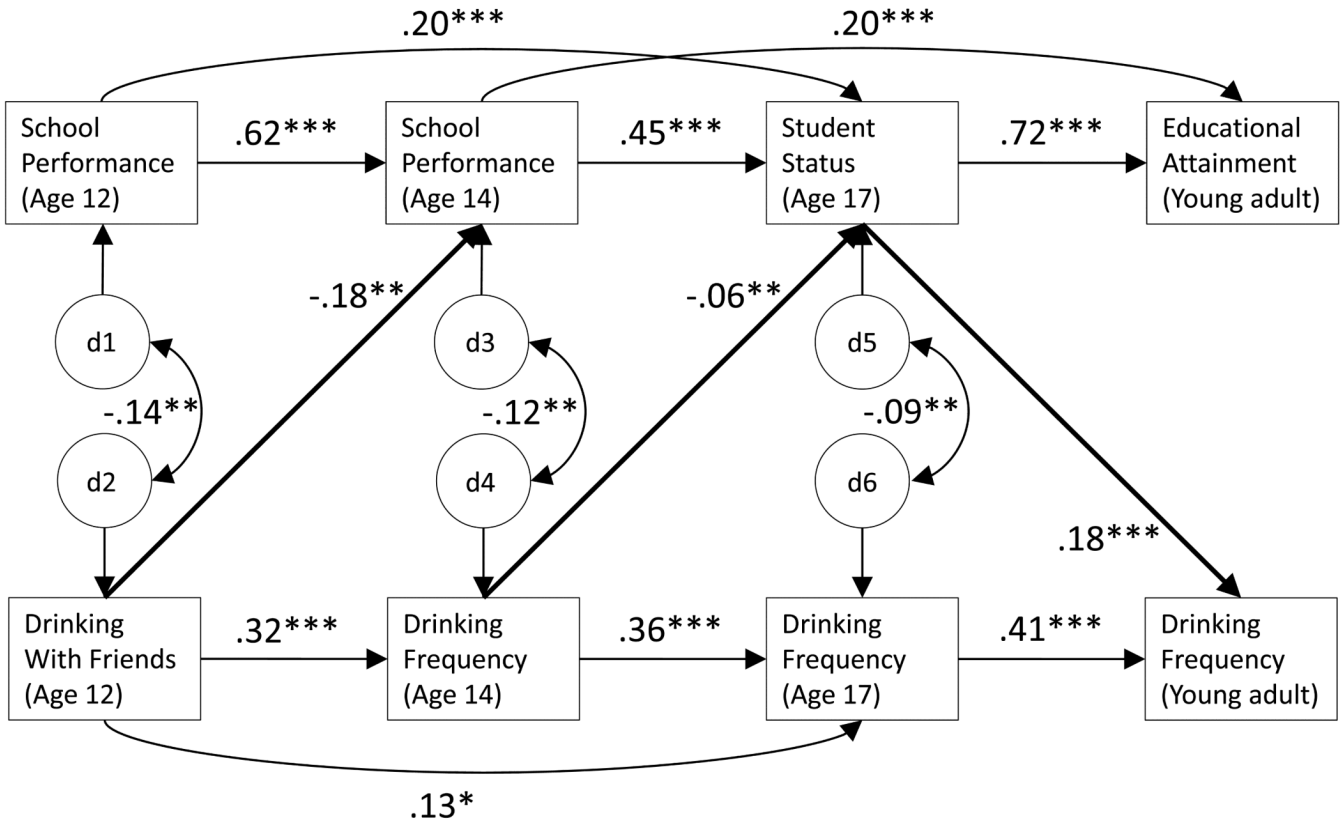

Figure 2.

Cross-lagged path model for educational achievement and frequency of drinking. Statistically significant standardized path coefficients are shown. The covariates sex, parental education, parental drinking and parental smoking were included in the model but are omitted from the figure. d, residual variance; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

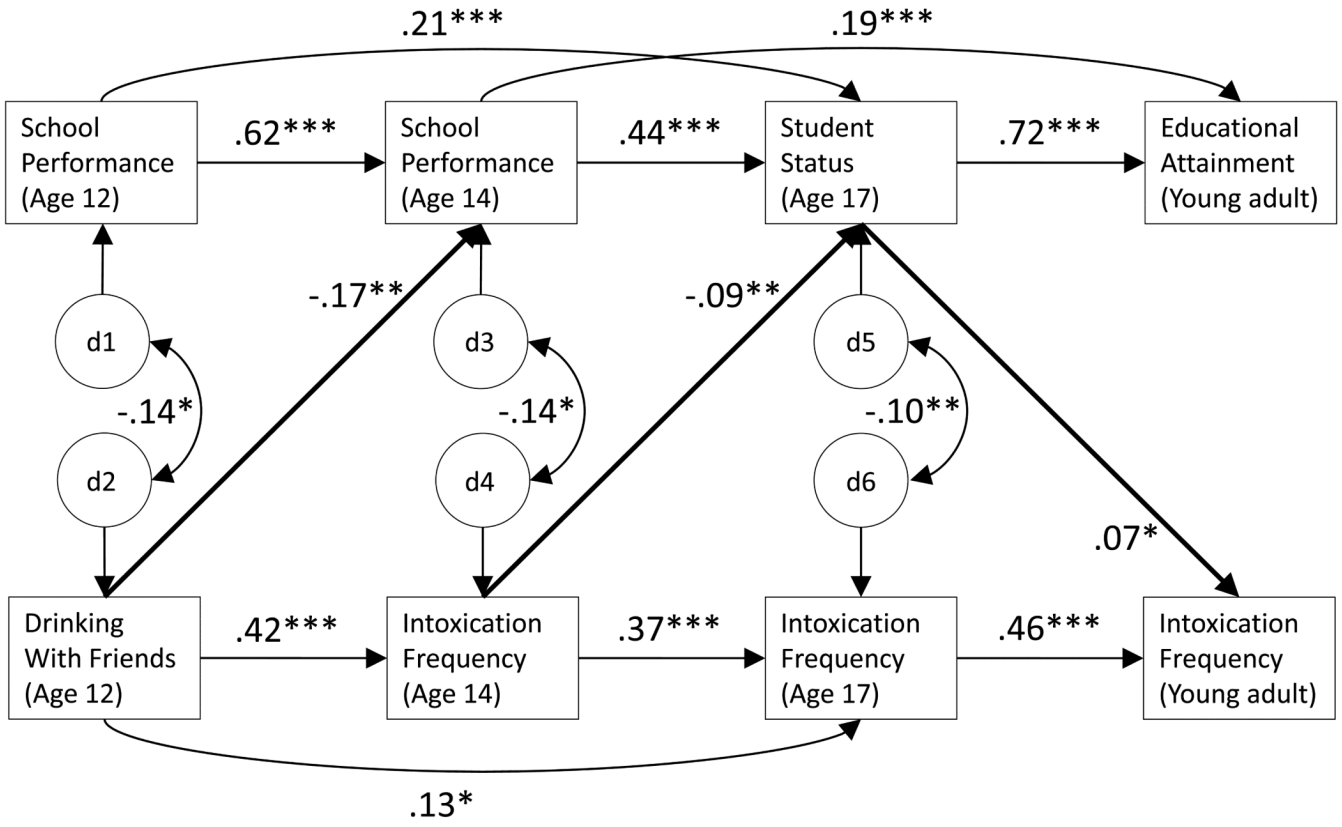

Figure 3.

Cross-lagged path model for educational achievement and frequency of intoxicating. Statistically significant standardized path coefficients are shown. The covariates sex, parental education, parental drinking and parental smoking were included in the model but are omitted from the figure. d, residual variance; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

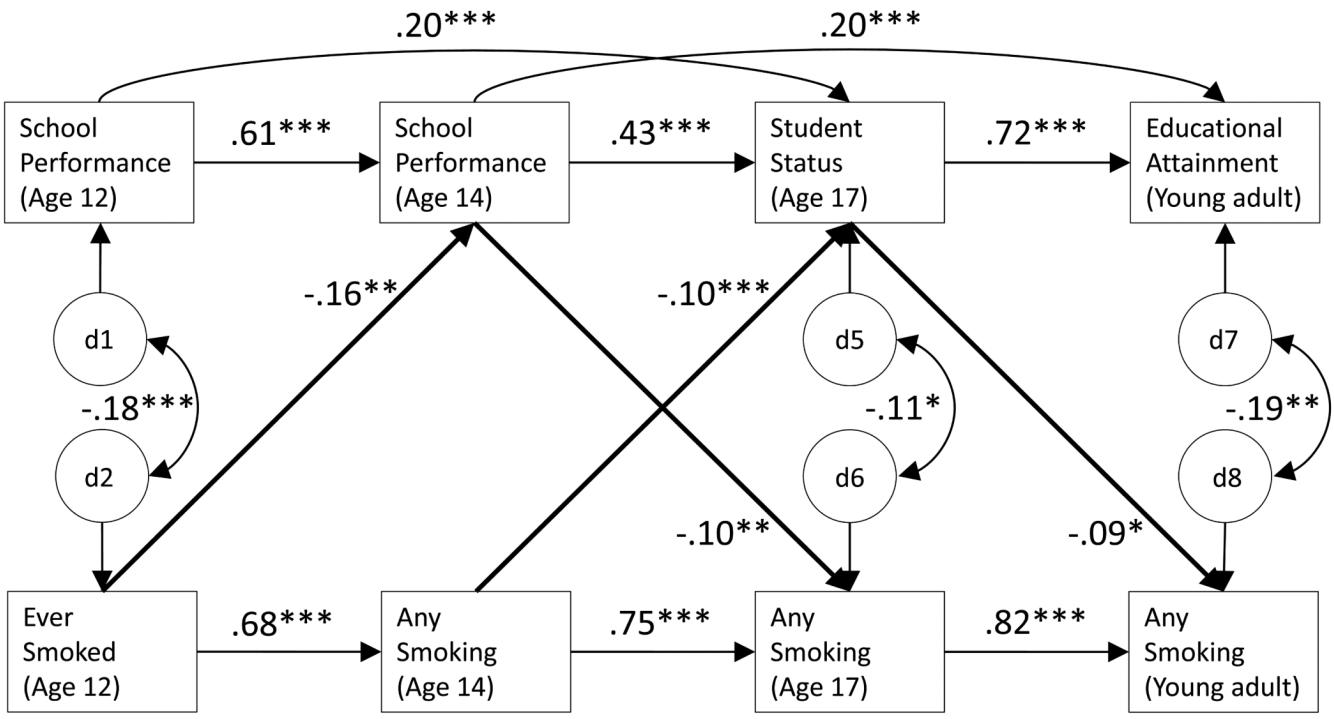

Figure 4.

Cross-lagged path model for educational achievement and any current smoking. Statistically significant standardized path coefficients are shown. The covariates sex, parental education, parental drinking and parental smoking were included in the model but are omitted from the figure. d, residual variance; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

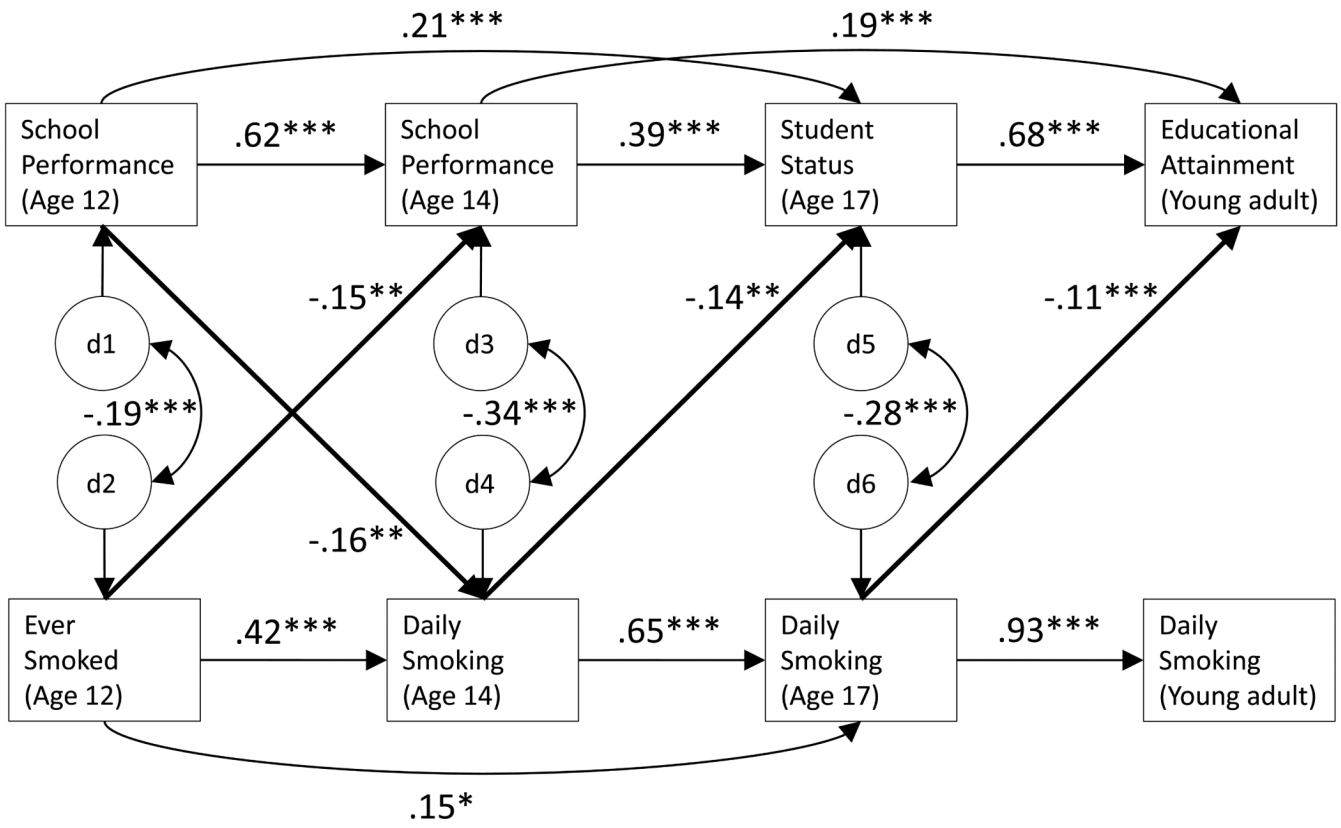

Figure 5.

Cross-lagged path model for educational achievement and daily smoking. Statistically significant standardized path coefficients are shown. The covariates sex, parental education, parental drinking and parental smoking were included in the model but are omitted from the figure. d, residual variance; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 1

Polychoric correlation matrix, mean (M), standard deviation (SD) and number of observations (N) for education and substance use variables.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.
1. GPA (W1)	1																	
2. GPA (W2)	.70	1																
3. Student status (W3)	.56	.63	1															
4. Education (W4)	.55	.67	.84	1														
5. Drinking (W1)	−.12	−.26	−.24	−.11[a]	1													
6. Drinking (W2)	−.07	−.17	−.15	−.14	.36	1												
7. Drinking (W3)	−.04	−.12	−.11	−.15	.26	.46	1											
8. Drinking (W4)	.09	.09	.14	.12	.07[a]	.22	.46	1										
9. Intoxicating (W2)	−.10	−.23	−.21	−.18	.45	.92	.45	.17	1									
10. Intoxicating (W3)	−.08	−.16	−.16	−.21	.30	.45	.87	.39	.47	1								
11. Intoxicating (W4)	−.01[a]	−.05[a]	.01[a]	−.02[a]	.20	.24	.46	.72	.23	.49	1							
12. Ever smoked (W1)	−.20	−.28	−.29	−.29	.61	.33	.28	.15	.43	.36	.20	1						
13. Any smoking (W2)	−.14	−.27	−.24	−.24	.49	.64	.42	.13	.73	.47	.22	.69	1					
14. Any smoking (W3)	−.17	−.30	−.30	−.31	.46	.54	.58	.25	.62	.68	.34	.57	.81	1				
15. Any smoking (W4)	−.17	−.29	−.29	−.36	.36	.36	.46	.27	.39	.51	.41	.43	.55	.74	1			
16. Daily smoking (W2)	−.23	−.50	−.38	−.40	.57	.63	.37	.09[a]	.72	.40	.19	.50	-[b]	.66	.52	1		
17. Daily smoking (W3)	−.26	−.36	−.44	−.49	.38	.45	.55	.16	.49	.58	.26	.44	.59	-[b]	.80	.74	1	
18. Daily smoking (W4)	−.17	−.28	−.33	−.42	.26	.34	.42	.21	.37	.46	.36	.35	.47	.67	-[b]	.53	.80	1
M	3.46	3.50	1.57	2.17	.06	.53	1.75	1.51	.31	1.22	1.50	.20	.43	.70	.40	.04	.25	.28
SD	.70	.86	.58	.97	.24	.81	.96	1.05	.62	.85	.81	.40	.49	.46	.49	.20	.43	.45
N	4,372	2,923	4,207	3,218	1,869	4,709	4,235	3,190	4,689	4,231	3,187	1,869	4,709	4,202	3,187	4,691	4,200	3,187

GPA, grade point average. W1-W4, study waves 1-4.

All variables are categorical; M and SD shown for descriptive purposes only.

[a] Correlation is non-significant (p>.05)

[b] Correlation cannot be estimated due to a zero cell in the bivariate table (i.e., all daily smokers are necessary smokers)