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Which adolescent factors predict alcohol misuse in young adulthood? A co-twin comparisons study

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Abstract

Background and aims—Research on adolescent predictors of later alcohol misuse is typically conducted on samples of singletons, and associations may be confounded by between-family differences. To address potential confounding, we applied a co-twin comparison design to evaluate whether differences between co-twins in a wide array of adolescent risk factors predicted differences in young adult alcohol misuse.

Design—Longitudinal study in which associations between characteristics of the sample as adolescents were used to predict young adult alcohol misuse in individual-level analyses and co-twin comparisons.

Setting—Finland.

Participants—A total of 3402 individuals (1435 complete twin pairs; 36% monozygotic; 57% female) from the FinnTwin12 study.

Measurements—The young adult alcohol misuse outcome was a composite score of alcohol use and intoxication frequency. Adolescent predictors included factor scores representing academic performance, substance use, externalizing problems, internalizing problems, peer environment, physical health and relationship with parents; and single measures tapping alcohol expectancies, life events and pubertal development.

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Declaration of interests

None.

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Figure S1. Supporting Information.

Data S1. Supporting Information.

Findings—In individual-level analyses, individuals with higher adolescent substance use, externalizing problems, time with friends, peer deviance, sports involvement, sleeping difficulties, parental discipline, positive alcohol expectancies and difficulty of life events reported higher alcohol misuse in young adulthood (*P*s < 0.019, R^2 = 0.0003–0.0310%). Conversely, those with higher adolescent internalizing problems, parent–child relationship quality and time with parents reported lower alcohol misuse (*P*s < 0021, R^2 = 0.0018–0.0093%). The associations with adolescent substance use and alcohol expectancies remained significant in co-twin comparisons (*P*s < 0.049, R^2 = 0.0019–0.0314%). Further, academic performance emerged as a significant predictor, such that individuals with higher grades compared with their co-twin reported higher young adult alcohol misuse (*P*s < 0.029, R^2 = 0.0449–0.0533%).

Conclusions—Adolescent substance use, positive alcohol expectancies and higher academic performance appear to be robust predictors of later alcohol misuse.

Keywords

Alcohol; adolescence; co-twin comparisons; FinnTwin12; fixed effects; young adulthood

INTRODUCTION

Alcohol use typically increases throughout adolescence and peaks during young adulthood [1–3]. Characterizing early adolescent predictors of later alcohol misuse can identify relevant targets for preventive intervention efforts and mitigate adverse alcohol-related outcomes, which range from lower educational attainment to heightened risk for cardiovascular disease and cancer [4–7]. However, the majority of studies examining prospective predictors of later alcohol misuse are conducted on samples of singletons [8–11], and associations may be confounded by between-family differences, such as socio-economic status and parenting practices. The co-twin comparison design addresses potential confounding by evaluating whether differences in adolescent risk factors between twins predict differences in their young adult alcohol misuse. Because twin siblings share a rearing environment and half or all their genetic variation, a co-twin comparison design assesses whether observed individual-level associations remain significant after controlling for factors that vary between families.

Adolescent predictors of later alcohol misuse range from characteristics of the individual to aspects of their social context [8,10]. In the current study, we focus on adolescent domains shown to be predictive of young adult alcohol use outcomes in prior studies, including academic achievement, peer environment, parent–child relationship characteristics, early adolescent substance use, physical health, externalizing behaviors and internalizing problems. Individuals with higher grades report lower alcohol use throughout adolescence [12] and young adulthood [13]. Further, social and familial factors, such as affiliations with deviant peers [12,14], lower levels of parental autonomy granting, monitoring, warmth and involvement [12,15,16]and higher levels of relational tension and discipline [15,17] are associated with increased risk for adolescent and young adult alcohol use and misuse.

Individual-level characteristics in adolescence, such as substance use, physical health, externalizing behaviors and internalizing problems, are also relevant for subsequent alcohol

misuse. There is significant continuity in substance use from adolescence to young adulthood [18,19], such that adolescents with higher cigarette use [8,20] and alcohol use [21] are at increased risk for later alcohol misuse. In addition, persistently inactive adolescents report more frequent intoxication than those who are physically active [22], and poor self-rated health [23] and sleeping difficulties [24,25] are positively associated with heavy drinking. Externalizing behaviors, including conduct problems, inattention and impulsivity, are also associated with alcohol use problems [9,11,26–28], although research examining the influence of internalizing problems is less clear [29]. Some studies suggest that low self-esteem [30] and more severe depressive symptoms [20,31] in adolescence increase risk for heavy drinking in young adulthood, while others indicate that social maladjustment [9] depressive affect [8] and increased social anxiety [32] predict fewer alcohol use problems.

As reviewed above, there is an extensive literature on the adolescent predictors of young adult alcohol misuse among samples of unrelated individuals. However, as with all observational research, these associations are prone to confounding by between-family differences, which may have significant implications for our understanding of pathways to young adult alcohol misuse. For instance, parental divorce is associated with both adolescent internalizing problems [33] and excessive alcohol use in young adulthood [20]. Thus, a family-level factor, such as parental divorce, could explain the observed association between internalizing problems and later alcohol misuse within samples of unrelated individuals. Co-twin comparisons address familial confounding and strengthen inferences in observational research by evaluating whether differences between twins in purported adolescent predictors map onto differences in alcohol-related outcomes [34–36], effectively controlling for the genetic and environmental influences that twin siblings share. Continuing the above example, if differences between twins in their internalizing problems predict differences in their young adult alcohol misuse, this suggests that the association between internalizing problems and alcohol misuse is not purely attributable to parental divorce (or any other factor shared by co-twins). Internalizing problems may therefore be an important target for alcohol misuse preventive intervention efforts. Conversely, if differences between twins in adolescence do not prospectively predict differences in alcohol misuse, this is consistent with confounding by familial factors (i.e. genetic and environmental influences, such as parental divorce, that twins share) or a causal pathway in which the adolescent predictor mediates genetic or shared environmental influences on subsequent alcohol misuse. Thus, co-twin comparisons can differentiate valuable targets for preventive intervention efforts from markers of non-causal familial liability. In prior studies, Irons *et al.* [37] and Savage *et al.* [38] used the co-twin design to examine adolescent alcohol exposure, parental monitoring and peer deviance as adolescent predictors of young adult alcohol misuse. When examined within families, associations with adolescent alcohol exposure and parental monitoring remained robust, although peer deviance was no longer a significant risk factor for subsequent alcohol misuse [37,38]. Such findings underscore the importance of using complementary methods, such as co-twin comparisons, to understand the nature of individual-level associations.

In the current study, we employed a co-twin comparison design in a sample of Finnish twins followed longitudinally from adolescence to young adulthood. We examined a series of

adolescent risk and protective factors for alcohol misuse, including academic performance, early adolescent substance use, externalizing problems, internalizing problems, parent–child relationship quality, peer environment and physical health. The alcohol misuse outcome included frequency of alcohol use and frequency of intoxication. Although these measures converge among individuals with high alcohol intake, heavy drinking occasions are a particularly important predictor of alcohol use disorder (AUD) among individuals with moderate alcohol consumption [39]. Our pre-registered hypotheses were informed by prior studies characterizing the genetic and environmental architecture of purported risk factors and alcohol-related outcomes [22,32,37,38,40–43]. We expected that academic performance, externalizing problems, physical health and relationship with parents would not be robust predictors of young adult alcohol misuse in co-twin comparison analyses. Conversely, we predicted that associations for alcohol expectancies and life events would be positive and robust. We did not have specific hypotheses for adolescent substance use, internalizing problems and peer environment due to contrasting hypotheses at the level of individual predictors. Our aims were as follows:

1. To evaluate adolescent predictors of young adult alcohol misuse in individual-level analyses, which are comparable to prior studies conducted on samples of unrelated individuals.
2. To use the co-twin comparison design to evaluate whether observed individual-level associations remain significant after controlling for genetic and environmental influences shared by twin siblings.

MATERIALS AND METHODS

Sample

Participants were from FinnTwin12, a population-based, longitudinal study of Finnish twins born 1983–87 [44,45]. Participants were identified through Finland's Central Population Registry. A family questionnaire was mailed to each twin family in the year before the twins reached age 12 years. This questionnaire was returned by 2724 families, 87% of those identified. For those who returned the family questionnaire, individual questionnaires were mailed to both parents and the two co-twins. Ratings were also completed by parents and teachers. Zygosity was determined based on co-twins' [46] and parents' [47] responses to items developed for zygosity classification, and sex was ascertained from Finland's Central Population Registry. Follow-up assessments occurred at ages 14, 17.5 and as young adults (average age = 22 years, range = 20–26 years). For the current study, adolescent predictors were derived from assessments at ages 12 and 14. Response rate for the age 14 assessment was 92%. We limited analyses to 3402 individuals (1435 complete twin pairs; 36% monozygotic; 57% female) who completed the young adult follow-up assessment; 66% of the original sample was retained throughout young adulthood. Sex significantly predicted young adult participation [odds ratio (OR) = 6.00, 95% confidence interval (CI) = 4.33, 8.29], such that females were six times more likely to participate in follow-up than males. Frequency of alcohol use (OR = 0.88, 95% CI = 0.77, 1.01) and frequency of intoxication at age 14 (OR = 0.88, 95% CI = 0.77, 1.00) did not significantly predict study retention.

Measures

Young adult alcohol use and intoxication frequency—Frequency of alcohol use in young adulthood was assessed with one item: 'How often do you drink alcohol?'. Frequency of intoxication was also assessed with one item: 'How often do you drink so that you get at least slightly intoxicated?'. Participants selected from nine response options. Responses were recoded as pseudo-continuous days of drinking per month and days intoxicated per month, respectively (daily = 30 days, a couple of times per week = 8 days, once per week = 4 days, a couple of times per month = 2 days, once per month = 1 day, bimonthly = 0.5 days, 2–4 times per year = 0.25 days, once per year or less = 0.083 days, never = 0 days; [48]).

Adolescent risk and protective factors—Table 1 provides information regarding measures of adolescent risk and protective factors. At ages 12 and 14, participants reported on their leisure time activities; participation in organized activities; sports participation; sleeping difficulties; parental autonomy granting, discipline, monitoring, tension and warmth; time spent with parents; and pubertal development. At age 14, participants also reported on their cigarette smoking; daily smoking; frequency of alcohol use; frequency of alcohol intoxication; self-esteem; peer deviance; peer drinking; peer drug use; peer smoking; perceived health; physical activity; alcohol expectancies; life events; and perceived difficulty of life events. In addition, parents and teachers provided ratings for grade point average, aggression, impulsivity, depression, social anxiety and social adjustment at age 12, and teachers reported on grade point average at age 14.

Statistical methods

The analytical plan for this project was pre-registered and can be viewed through the Open Science Framework (https://osf.io/3vrn5/register/565fb3678c5e4a66b5582f67). We grouped adolescent predictors into the following domains: academic performance, early adolescent substance use, externalizing problems, internalizing problems, peer environment and relationship with parents. Following basic descriptive statistics and log-transformation of skewed variables, we performed a series of analyses aimed at item reduction using a split-half exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) approach. To do this, we split the sample into two, randomly selecting one twin from each pair for inclusion in each split-half. The first split-half sample included 1440 unrelated individuals, and the second split-half sample included the remaining 1431 individuals. Within each categorized domain, we determined the number of retained factors based on several complementary methods: parallel analysis [49], the Kaiser rule [50], number of factors needed to account for 60% of the total variance [51] and scree plots [52]. We conducted EFA in the first split-half using the 'umxEFA' function in the R {umx} package [53]. We used a factor loading cut-off of 0.40. We then conducted CFA in the first split-half using the 'cfa' function in the R {lavaan} package [54]. We used maximum likelihood estimation, with a comparative fit index (CFI) > 0.90 and a standardized root mean squared residual (SRMR) < 0.08 as criteria for acceptable model fit [55]. We conducted CFA in the second split-half to re-evaluate the model derived from the initial half. Finally, we used the 'lavPredict' function in {lavaan} [54] to derive factor scores for the full sample within each categorized domain. Several variables (alcohol expectancies, life events, perceived difficulty of life events and pubertal development) did not clearly fit into the domains identified above. For this reason,

these predictors were examined separately and were not included in item reduction. For our alcohol misuse outcome, we created an overall sum score for frequency of alcohol use and frequency of intoxication ($r = 0.64$).

First, we examined associations of each factor score with alcohol misuse in individual-level analyses, using a linear mixed model to adjust for non-independence of individuals within the same family. We then conducted co-twin comparisons using a twin fixed-effects model, which evaluates whether observed individual-level associations remain significant after controlling for genetic and environmental influences shared by co-twins. Each factor score was examined in a separate model to avoid potential problems with collinearity or suppression effects. Additional information on the twin fixed-effects model can be found in the Supporting information. Finally, we conducted a series of co-twin comparisons for monozygotic (MZ) twins (251 pairs), who share 100% of their genetic variation, to enable more stringent control for shared genetic variation. All analyses were run using the R {plm} package version 1.6–6 [56] and included sex as a covariate. We adopted a *P*-value threshold of 0.05, given that our directional hypotheses and analytical plan were pre-registered, which is consistent with Nosek *et al.* [57] and Rubin [58].

Non-significant co-twin associations may reflect influences of familial factors; alternatively, null associations may be driven by insufficient variability between twins [59]. We explored the latter possibility in two ways. First, we calculated twin correlations for the overall sample and sample of MZ twins only. Next, we used the 'phtest' function in the R {plm} package [56] to conduct the Durbin–Wu–Hausman test [60], allowing us to more formally examine whether non-significant co-twin associations were explained by insufficient within-family variability.

RESULTS

The Supporting information contains detailed information regarding EFA/CFA for item reduction, inter-item correlations within each domain (Supporting information, Tables S1–S6), criteria for factor retention (Supporting information, Table S7, Fig. S1), factor loadings for EFA in the first split-half sample (Supporting information, Table S8), loadings used to construct factor scores (Supporting information, Table S9) and basic descriptive statistics (Supporting information, Table S10). On average, participants reported 3.79 days of drinking per month [standard deviation (SD) = 4.36] and 1.23 days intoxicated per month (SD = 1.23). Measures included within each factor score are summarized in Table 2. Results for individual-level and co-twin analyses are shown in Table 3 and Fig. 1, which presents beta hat estimates by analysis type (individual-level, co-twin comparisons and comparisons of MZ twins only). We review results from the individual-level and co-twin analyses below.

Individual-level analyses

In individual-level analyses, adolescents with higher substance use, externalizing problems, time spent with friends, peer deviance, sports involvement, sleeping difficulties at ages 12 and 14, parental discipline, perceived difficulty of life events and positive alcohol expectancies reported higher alcohol misuse in young adulthood. By contrast, individuals with higher parent- and teacher-reported internalizing problems, time spent with parents and

parent–child relationship quality at ages 12 and 14 exhibited lower risk for alcohol misuse. Adolescent academic performance, perceived health, physical activity, pubertal development and adolescent stressful life events did not significantly predict young adult alcohol misuse.

Co-twin comparisons

When tested using co-twin comparisons, early adolescent substance use and positive alcohol expectancies positively predicted young adult alcohol misuse. Further, adolescent academic performance emerged as a significant predictor, such that individuals with higher grades in adolescence compared to their co-twin reported higher young adult alcohol misuse. Associations with externalizing problems, parent- and teacher-reported internalizing problems, time spent with friends, peer deviance, sports involvement, sleeping difficulties at ages 12 and 14, parental discipline, time spent with parents, parent–child relationship quality at ages 12 and 14 and perceived difficulty of life events were no longer significant.

Co-twin comparisons (MZ twins only)

Adolescent academic performance positively predicted young adult alcohol misuse in comparisons of MZ twins. Associations with early adolescent substance use and positive alcohol expectancies were no longer significant, although the point estimate for alcohol expectancies was not markedly reduced (Fig. 1).

Sensitivity analyses

As shown in Table S11, twin correlation coefficients ranged from 0.10 to 0.65 in the overall sample and from 0.15 to 0.87 in the MZ-only sample. The Durbin–Wu–Hausman test was significant for associations with externalizing problems, time with friends, peer deviance, age 14 sleeping difficulties, parental discipline, perceived difficulty of life events, age 14 parent–child relationship quality and time with parents (Ps < 0.045), suggesting that a within-family estimator is more efficient than a between-family estimator. Because there was sufficient within-family variability to examine associations between each of these adolescent factors and young adult alcohol misuse, the non-significant co-twin associations for these factors are most consistent with confounding by familial influences. By contrast, the Durbin–Wu–Hausman test was not significant for sports involvement, age 12 sleeping difficulties, internalizing problems and age 12 parent–child relationship quality (Ps > 0.063), which is consistent with the interpretation that the non-significant co-twin comparisons for these factors may reflect insufficient variability between twins to detect an effect.

DISCUSSION

We employed a co-twin comparison design to evaluate the degree to which adolescent predictors of young adult alcohol misuse were robust versus attributable to familial influences. In individual-level analyses, we found that individuals with higher adolescent substance use, externalizing problems, time spent with friends, peer deviance, sports involvement, sleeping difficulties, parental discipline, positive alcohol expectancies and perceived difficulty of life events reported higher alcohol misuse in young adulthood. Conversely, those with higher internalizing problems, parent–child relationship quality and time with parents reported lower alcohol misuse. These findings are consistent with an

extensive literature examining adolescent predictors of young adult alcohol misuse among samples of unrelated individuals [8,9,11–20,24–28,61]. Internalizing problems have been identified as both a risk [20,30,31] and protective [8,9,38] factor for alcohol use problems in prior studies; in the present study, adolescent internalizing problems predicted lower young adult alcohol misuse. Our findings, using non-clinical depression and social anxiety measures, are consistent with prior research in Finland demonstrating that social anxiety protects against subsequent alcohol use [32], but should be considered tentative in the context of the broader, mixed literature on the relationship between internalizing problems and alcohol misuse.

Co-twin comparisons complement individual-level analyses by examining whether differences between twins in adolescence predict differences in young adult alcohol misuse after controlling for genetic and environmental influences that twin siblings share. When tested using co-twin comparisons, associations with adolescent substance use and positive alcohol expectancies remained significant. Further, academic performance did not predict alcohol misuse in individual-level analyses but emerged as a significant predictor after controlling for genetic and environmental influences that twins share. A positive and robust association between adolescent academic performance and young adult alcohol misuse was unexpected, as prior studies have identified early adolescent academic achievement as a protective factor for alcohol misuse [12,13]. However, previous work in the FinnTwin12 sample has similarly demonstrated that educational attainment at age 17 positively predicts frequency of alcohol use in young adulthood [62]. One potential explanation is that the higher achieving twin may have been more likely to attend university, and heavy drinking is prevalent in early years of study at university [63]. Adolescent academic performance predicts higher educational attainment at the young adult assessment [62], strengthening the plausibility of this explanation.

These findings lend valuable insight into relevant targets for preventive intervention efforts. We found that adolescent academic performance, substance use and positive alcohol expectancies were robust predictors of young adult alcohol misuse when evaluating differences between twins, supporting these factors as valuable targets for preventive intervention efforts or for identifying individuals who are at particular risk. In contrast, many previously documented adolescent risk and protective factors for young adult alcohol misuse, such as externalizing behaviors and peer deviance, were not robust in co-twin comparison analyses. The absence of significant co-twin associations does not conclusively eliminate these factors as valuable targets for preventive intervention efforts. For example, it remains plausible that these adolescent predictors mediate genetic and shared environmental influences on alcohol misuse. Adolescent factors within these causal familial pathways would exhibit reduced co-twin associations but remain effective targets for preventive intervention. Our findings should therefore be verified across multiple methodologies with varied assumptions [64] before recommendations for preventive intervention programs are warranted.

Our results should be considered in light of several limitations. First, although the co-twin design permits control for genetic and environmental influences that twins share, confounding by unmeasured individual-level characteristics remains plausible and precludes

a strong causal interpretation of results. For example, if one co-twin experienced a traumatic event, differential trauma exposure between twins could explain the observed association between adolescent substance use [65] and young adult alcohol misuse [66]. Secondly, among statistically significant adolescent predictors, several 95% confidence intervals approached zero (Table 3), including individual-level analyses for parent-reported internalizing and age 12 sleeping difficulties, as well as co-twin analyses for academic performance and adolescent substance use. These findings should be interpreted carefully prior to replication by future work. Thirdly, co-twin analyses involve increased risk of Type 2 error when compared to individual-level analyses, as co-twin associations compound measurement error [67] and involve an effective reduction in sample size [59]. Results from comparisons of MZ twins only should be interpreted with caution, given reduced power to detect effects in this subset (251 pairs). Finally, limitations of the available measures and sample characteristics should be noted. Several adolescent predictors (e.g. aggression, impulsivity, social anxiety) were parent-reported and may therefore reflect the parent's perception rather than the adolescent's actual behavior. In addition, it unknown whether the effects observed in our Finnish population-based sample will generalize broadly to other populations, although it is encouraging that much of the literature on alcohol use and misuse in Finland replicates across Europe and the United States (and vice versa; e.g. [68,69]).

Co-twin comparison designs enable stronger inferences not possible in samples of unrelated individuals by controlling for genetic and environmental influences that twins share. The current study yields novel insights by using a co-twin comparison design to examine a range of adolescent risk and protective factors for young adult alcohol misuse. Although many well-known adolescent correlates of young adult alcohol use problems, such as externalizing and internalizing problems, were not robust predictors of young adult alcohol misuse, our results support early adolescent substance use and positive alcohol expectancies as valuable targets for preventive intervention efforts aiming to reduce alcohol misuse in young adulthood.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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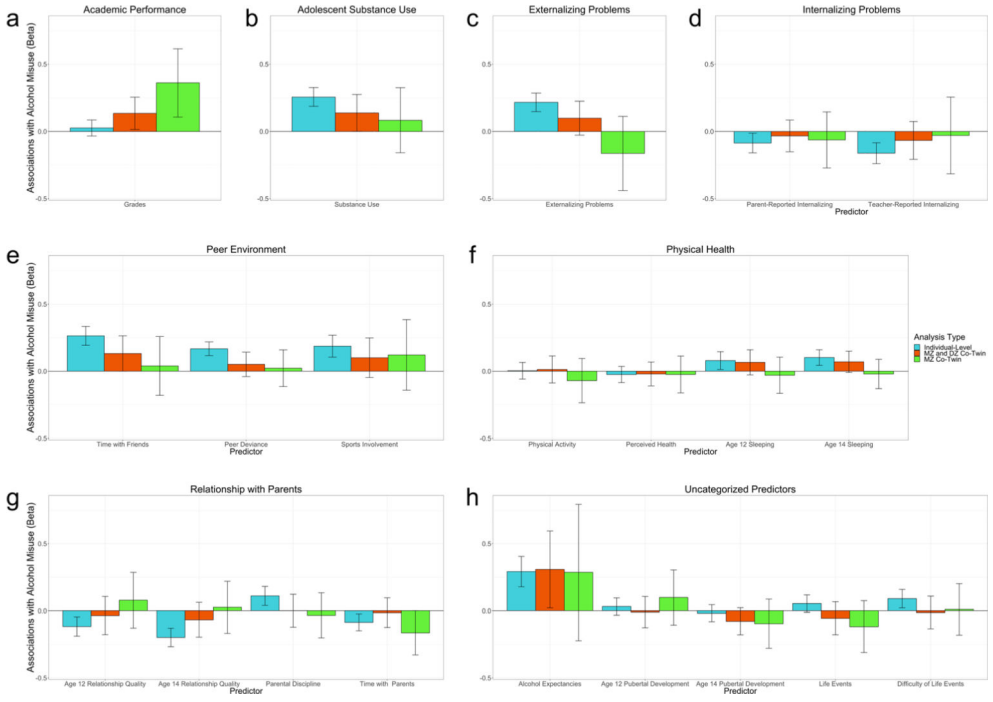

Figure 1.

Examining adolescent predictors of young adult alcohol misuse in individual-level and co-twin comparisons. Error bars denote 95% confidence intervals of estimates [Colour figure can be viewed at wileyonlinelibrary.com]

Table 1

Adolescent predictors for young adult alcohol misuse.

ACA	Grades (PR)	'Which twin had the higher grade point average last spring?'; age 12
	Grades (TR)	Grade point average using the Finnish GPA system (1 = below 6 to 5 = above 9); ages 12 and 14
SUB	Cigarette smoking	Two items: 'Have you ever smoked?', 'How many cigarettes have you smoked?'. Recoded, such that 0 = never smoked to 4 = smoked more than 50 cigarettes [70]; age 14
	Daily smoking	Present smoking habits (0 = smokes, but not daily to 1 = smokes at least once per day) [62]; age 14
	Frequency of alcohol use	'How often do you drink alcohol?' Recoded as days of drinking per month; age 14
	Frequency of intoxication	'How often do you drink alcohol so that you get at least slightly intoxicated?' Recoded as days intoxicated per month; age 14
EXT	Aggression (PR/TR)	Aggression subscale of MPNI [71]; age 12
	Impulsivity (PR/TR)	Hyperactivity–impulsivity subscale of MPNI [71]; age 12
INT	Depression (PR/TR)	Depression subscale of MPNI [71]; age 12
	Self-esteem	10-item Rosenberg Self-Esteem Scale [72]; age 14
	Social anxiety (PR/TR)	Social anxiety subscale of MPNI [71]; age 12
PEER ENV	Adjustment (PR/TR)	Adjustment subscale of MPNI [71]; age 12
	Leisure time activities	Three items: frequency of spending 'time with friends in your home', 'time with friends in their home', 'time with friends in places where youth meet up' (1 = daily to 5 = never). Recoded as number of activities with friends per month; ages 12 and 14
	Organized activities	Frequency of participation in 'clubs, boy/girl scouts, or other organized activities' (1 = daily to 5 = never). Recoded as number of organized activities per month; ages 12 and 14
	Peer deviance	Number of friends who drink, smoke, use drugs, or get into trouble at school [73]; age 14
	Peer drinking	Number of friends who drink alcohol (1 = none to 4 = more than 5); age 14
	Peer drug use	Number of acquaintances who have tried drugs (1 = none to 4 = more than 5); age 14
	Peer smoking	Number of friends who smoke cigarettes (1 = none to 4 = more than 5); age 14
	Sports participation	Frequency of participation in team sports (1 = daily to 5 = never). Recoded as number of sports-related activities per month; ages 12 and 14.
HEA	Perceived health	'How do you rate your health?' (1 = very poor to 5 = very good); age 14
	Physical activity	'How often do you exercise or do sports during your free time?' (1 = never to7 = just about every day). Recoded as number of times engaged in physical activity per month; age 14.
	Sleeping difficulties	'How often have you experienced difficulties falling asleep since last summer?' (0 = rarely or never to 4 = about once a month). Recoded as number of nights affected by sleeping problems per month; ages 12 and 14
PARENTS	Autonomy granting	Four items: 'my parents listen to my opinions', 'my parents give me credit', 'my parents encourage me to be independent', 'my parents try to clear things by talking when I've behaved badly' (1 = rarely to 4 = never) [15]; ages 12 and 14
	Discipline	Two items: 'my parents punish me if I do something I'm not supposed to' (1 = rarely to 4 = never); 'strict' home atmosphere (1 = does not hold true to 5 = holds completely true) [15]; ages 12 and 14
	Monitoring	Three items: 'my parents know my plan for the day', 'my parents know my interests, activities, and whereabouts', 'my parents know where I am and who I'm with when I'm not at home' (1 = rarely to 4 = never)[15]; ages 12 and 14

	Tension	Three items: home atmosphere is ‘unfair’, ‘quarrelsome’, ‘indifferent’ (1 = does not hold true to 5 = holds completely true) [15]; ages 12 and 14
	Time with parents	Six items: frequency of engaging in ‘discussions’, ‘movies’, ‘sports’, ‘hobbies’, ‘camping/traveling/visiting’, and ‘outdoor recreation’ with parents (1 = every day to 5 = never). Recoded as number of activities with parents per month; ages 12 and 14
	Warmth	Four items: home atmosphere is ‘warm/caring’, ‘encouraging/supportive’, ‘trusting/understanding’, ‘open’ (1 = does not hold true to 5 = holds completely true) [15]; ages 12 and 14
UNCAT	Alcohol expectancies	Degree to which alcohol makes people ‘sleepy’, ‘talkative’, ‘sad’, ‘angry’, ‘ill’, ‘friendly’, ‘confused’, ‘mean’, ‘content’, ‘fun’, ‘depressed’ (1 = never to 3 = often); age 14
	Difficulty of life events	‘How difficult were these changes for you overall?’ (1 = changes have been positive to 5 = changes have been difficult); age 14
	Life events	Checklist of 15 stressful life events experienced in the past two years; age 14
	Pubertal development	Pubertal Development Scale [74]. Recoded as within-sex z-scores; ages 12 and 14

ACA = academic performance; SUB = early adolescent substance use; EXT = externalizing problems; INT = internalizing problems; PEER ENV = peer environment; HEA = physical health; PARENTS = relationship with parents; UNCAT = uncategorized predictors; PR = parent-reported; TR = teacher-reported; MPNI = Multidimensional Peer Nomination Inventory.

Table 2

Measures used to construct factor scores within each domain.

	Factor	Measures
ACA	Academic performance	Grades (TR; age 12)
		Grades (TR; age 14)
SUB	Substance use	Cigarette smoking
		Frequency of alcohol use
		Frequency of intoxication
EXT	Externalizing problems	Aggression (TR)
		Impulsivity (PR)
		Impulsivity (TR)
INT	Parent-reported internalizing	Depression (PR)
		Social anxiety (PR)
	Teacher-reported internalizing	Depression (TR)
		Social anxiety (TR)
PEER ENV	Time with friends	Leisure time activities (age 12)
		Leisure time activities (age 14)
	Peer deviance	Peer deviance
		Peer drinking
		Peer drug use
		Peer smoking
	Sports involvement	Sports participation (age 12)
		Sports participation (age 14)
PARENTS	Age 12 relationship quality	Autonomy granting (age 12)
		Monitoring (age 12)
		Tension (age 12)
		Warmth (age 12)
	Age 14 relationship quality	Autonomy granting (age 14)
		Monitoring (age 14)
		Tension (age 14)
		Warmth (age 14)
	Parental discipline	Discipline (age 12)
	Time with parents	Time with parents (age 12)

All results in text refer to factor scores. ACA = academic performance; SUB = early adolescent substance use; EXT = externalizing problems; INT = internalizing problems; PEER ENV = peer environment; PARENTS = relationship with parents; PR = parent-reported; TR = teacher-reported.

Table 3

Results for individual-level and co-twin analyses.

		Analysis type	$\hat{\beta}$ (95% CI)	P	ΔR^2
ACA	Academic performance	Individual	0.026 (−0.034, 0.086)	0.39	0.0252
		Co-twin	0.135 (0.014, 0.256)	0.029	0.0533
		Co-twin MZ	0.361 (0.107, 0.615)	0.006	0.0449
SUB	Substance use	Individual	0.257 (0.188, 0.326)	< 0.001	0.0178
		Co-twin	0.139 (0.001,0.277)	0.049	0.0019
		Co-twin MZ	0.083 (−0.159, 0.325)	0.50	0.0010
EXT	Externalizing problems	Individual	0.217 (0.148, 0.287)	< 0.001	0.0113
		Co-twin	0.099 (−0.027, 0.226)	0.13	0.0004
		Co-Twin MZ	−0.164 (−0.440, 0.113)	0.25	0.0028
INT	Parent-reported internalizing	Individual	−0.087 (−0.160, −0.013)	0.021	0.0018
		Co-twin	−0.033 (−0.151, 0.085)	0.59	−0.0011
		Co-twin MZ	−0.063 (−0.272, 0.146)	0.55	0.0007
	Teacher-reported internalizing	Individual	−0.162 (−0.240, −0.084)	< 0.001	0.0051
		Co-twin	−0.067 (−0.208, 0.075)	0.36	−0.0007
		Co-Twin MZ	−0.030 (−0.316, 0.257)	0.84	0.0001
PEER ENV	Peer deviance	Individual	0.167 (0.116, 0.219)	< 0.001	0.0120
		Co-twin	0.051 (−0.040, 0.142)	0.27	0.0010
		Co-twin MZ	0.022 (−0.115, 0.159)	0.75	0.0002
	Sports involvement	Individual	0.187 (0.105, 0.269)	< 0.001	0.0060
		Co-twin	0.100 (−0.047, 0.248)	0.18	0.0014
		Co-twin MZ	0.121 (−0.142, 0.385)	0.37	0.0017
	Time with friends	Individual	0.264 (0.193, 0.334)	< 0.001	0.0157
		Co-twin	0.132 (0.000, 0.264)	0.051	0.0029
		Co-twin MZ	0.039 (−0.180, 0.259)	0.73	0.0003
HEA	Age 12 sleeping difficulties	Individual	0.079 (0.013, 0.146)	0.019	−0.0003
		Co-twin	0.066 (−0.028, 0.160)	0.17	−0.0045
		Co-twin MZ	−0.030 (−0.165, 0.105)	0.66	0.0005
	Age 14 sleeping difficulties	Individual	0.102 (0.044, 0.160)	0.001	0.0034

		Analysis type	$\hat{\beta}$ (95% CI)	P	ΔR^2
		Co-twin	0.070 (−0.009, 0.149)	0.084	−0.0016
		Co-twin MZ	−0.021 (−0.130, 0.089)	0.71	0.0003
	Perceived health	Individual	−0.025 (−0.085, 0.036)	0.42	0.0019
		Co-twin	−0.021 (−0.110, 0.068)	0.65	−0.0008
		Co-twin MZ	−0.025 (−0.162, 0.113)	0.73	0.0003
	Physical activity	Individual	0.003 (−0.059, 0.065)	0.92	0.0012
		Co-twin	0.013 (−0.088, 0.113)	0.80	−0.0008
		Co-twin MZ	−0.070 (−0.236, 0.095)	0.40	0.0015
PARENTS	Age 12 relationship quality	Individual	−0.117 (−0.188, −0.045)	0.001	0.0030
		Co-twin	−0.036 (−0.178, 0.107)	0.62	0.0002
		Co-twin MZ	0.079 (−0.129, 0.286)	0.46	0.0011
	Age 14 relationship quality	Individual	−0.198 (−0.267, −0.129)	< 0.001	0.0093
		Co-twin	−0.067 (−0.196, 0.063)	0.31	0.0007
		Co-twin MZ	0.026 (−0.168, 0.219)	0.80	0.0001
PARENTS	Parental discipline	Individual	0.110 (0.040, 0.181)	0.002	0.0028
		Co-twin	0.000 (−0.122, 0.123)	0.99	0.0000
		Co-twin MZ	−0.034 (−0.201, 0.134)	0.69	0.0003
	Time with parents	Individual	−0.086 (−0.149, −0.023)	0.008	0.0021
		Co-twin	−0.014 (−0.124, 0.096)	0.81	0.0000
		Co-twin MZ	−0.164 (−0.328, 0.000)	0.051	0.0077
UNCAT	Age 12 pubertal development	Individual	0.032 (−0.032, 0.095)	0.33	0.0008
		Co-twin	−0.010 (−0.126, 0.107)	0.87	−0.0040
		Co-twin MZ	0.099 (−0.106, 0.304)	0.35	0.0020
	Age 14 pubertal development	Individual	−0.018 (−0.081, 0.045)	0.57	0.0004
		Co-twin	−0.078 (−0.179, 0.022)	0.13	−0.0021
		Co-twin MZ	−0.096 (−0.279, 0.087)	0.30	0.0024
	Alcohol expectancies	Individual	0.292 (0.178, 0.405)	< 0.001	0.0310
		Co-twin	0.308 (0.021, 0.594)	0.037	0.0314
		Co-twin MZ	0.286 (−0.223, 0.795)	0.28	0.0181
	Difficulty of life events	Individual	0.090 (0.021, 0.159)	0.011	−0.0063
		Co-Twin	−0.013 (−0.134, 0.109)	0.84	−0.0193

	Analysis type	$\hat{\beta}$ (95% CI)	P	ΔR^2
Life events	Co-twin MZ	0.010 (−0.181, 0.202)	0.92	0.0000
	Individual	0.054 (−0.011, 0.118)	0.10	0.0021
	Co-twin	−0.056 (−0.178, 0.067)	0.38	−0.0005
	Co-twin MZ	−0.118 (−0.311, 0.075)	0.23	0.0031

ΔR^2 refers to the change in variance explained from a sex-only baseline model. ACA = academic performance; SUB = early adolescent substance use; EXT = externalizing problems; INT = internalizing problems; PEER ENV = peer environment; HEA = physical health; PARENTS = relationship with parents; UNCAT = uncategorized predictors; CI = confidence interval' MZ = monozygotic.