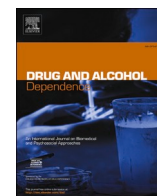




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Registered report

# Solitary alcohol use in adolescence predicts alcohol problems in adulthood: A 17-year longitudinal study in a large national sample of US high school students

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## ABSTRACT

**Background:** Identifying risk factors for alcohol use disorder (AUD) is important for public health. The social context of drinking—such as drinking alone—may be an independent and robust early risk marker for AUD symptoms later in life. We evaluated whether solitary alcohol use in adolescence (age 18) and young adulthood (age 23/24) was concurrently associated with binge drinking and prospectively predicted age 35 AUD symptoms, and whether associations differed by sex.

**Methods:** Longitudinal data were from the Monitoring the Future study. Surveys were completed by adolescents in 12th grade at age 18 (1976–2002), young adults at age 23/24 (1981–2008), and adults at age 35 (1993–2019). Analyses included past 12-month alcohol users ( $n = 4464$  for adolescent models;  $n = 4561$  for young adult models). Multivariable regression analyses tested whether adolescent and young adult solitary alcohol use was associated concurrently with binge drinking frequency and prospectively with age 35 AUD symptoms.

**Results:** Solitary alcohol use in adolescence and young adulthood was associated (a) concurrently with binge drinking and (b) prospectively with increased risk of age 35 AUD symptoms (even after controlling for earlier binge drinking, alcohol use frequency, and sociodemographic covariates). Adolescent solitary alcohol use was associated with age 35 AUD symptoms particularly among females; no interaction was observed between sex and young adult solitary alcohol use in predicting age 35 AUD symptoms.

**Conclusions:** Adolescent and young adult solitary alcohol use was associated with increased adult AUD symptoms above and beyond other risk factors; adolescent female solitary alcohol users were especially at risk.

## 1. Introduction

Excessive alcohol use is one of the leading risk factors for population health worldwide (Griswold et al., 2018), contributing to 3 million deaths globally each year and accounting for 7.1% and 2.2% of the global burden of disease for males and females, respectively (World Health Organization, 2019). The health burden attributable to alcohol use increases substantially in adolescence and young adulthood (Degenhardt et al., 2016). Beyond health consequences, excessive alcohol use contributes to significant individual and societal social and economic costs (Thavorncharoensap et al., 2009). It is essential to identify and respond to early risk factors for alcohol misuse in order to reduce the prevalence and severity of alcohol use disorder (AUD) in adults (Hawkins et al., 1992; Levy et al., 2016; Schulenberg et al., 2015).

Adolescence and young adulthood are key developmental periods for initiation and escalation of alcohol use (Brown et al., 2008; Chung et al., 2018; O'Malley et al., 1998; Patrick et al., 2013; Patrick and Schulenberg, 2014), and young people are at highest risk of experiencing substance use-related negative health consequences (Degenhardt et al., 2016; Gore et al., 2011; Johnston et al., 2010; National Center on Addiction and Substance Abuse, 2011). As such, the American Academy of Pediatrics (Hagan et al., 2017) and the American Medical Association (Alderman, 1994; Curry et al., 2018) along with other major health organizations (Kann et al., 2014; Maternal and Child Health Bureau, 2011; National Institute on Alcohol Abuse and Alcoholism, 2011; Substance Abuse and Mental Health Services Administration, 2021; U.S. Department of Health and Human Services, 2016), recommend universal substance use screening for adolescents and young adults whenever

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they receive medical care with referral to intervention as appropriate. Commonly, physicians and other medical professionals screen for risky alcohol use in young people by asking about the frequency and quantity of their alcohol consumption (Babor and Higgins-Biddle, 2000; Kulig, 2005; Levy et al., 2016), as these are thought to be some of the most telling signs for future alcohol problems (Chung et al., 2012; Yuen et al., 2020). Indeed, many alcohol use screening tools contain only questions about frequency and quantity of drinking (American Academy of Family Physicians, 2021; Babor et al., 2006; Centers for Disease Control and Prevention, 2014; NIAAA, 2011).

One underappreciated risk factor for the development of problematic drinking is the social context in which adolescents and young adults consume alcohol (Creswell, 2021; Mason et al., 2020). In particular, solitary alcohol use in adolescence and young adulthood may be associated with high-risk drinking and the development of alcohol problems (Skrzynski and Creswell, 2020). The vast majority of research on solitary alcohol use has been cross-sectional, though, and the few longitudinal studies that have been conducted used relatively small sample sizes that were restricted to certain geographical regions in the US (Creswell et al., 2014; Tucker et al., 2006; Waddell et al., 2021). Still, solitary alcohol use in adolescence and young adulthood may represent an informative divergence from normative behavior, as the vast majority of young people who drink alcohol only do so in the company of others (Mason et al., 2020; Sayette et al., 2012, 2016; Skrzynski and Creswell, 2020), citing “to have a good time with friends” as the primary reason for their alcohol use (Johnston & O’Malley, 1986; Patrick et al., 2011; Patrick et al., 2017; Terry-McElrath et al., 2017). Solitary alcohol use may be an early warning signal for the development of alcohol problems, above and beyond other early risk factors, for the approximately 14–15% of adolescents (Mason et al., 2020; Skrzynski and Creswell, 2020; Terry-McElrath et al., 2021) and 15–24% of young adults (Skrzynski and Creswell, 2020) who report drinking alone. The current study tests this hypothesis using large national samples of US adolescents followed into adulthood.

The nature of the association between solitary alcohol use and later alcohol use problems may follow two paths. First, solitary alcohol use at any particular age may be concurrently associated with high-risk drinking (such as binge drinking), which has been shown to predict alcohol use problems later in life (Creswell et al., 2020; Merline et al., 2008; Patrick et al., 2011; Schulenberg et al., 2015). Second, solitary alcohol use at any particular age could be a unique predictor of later alcohol use problems independent of its associations with concurrent high-risk drinking. This would provide compelling evidence that solitary alcohol use is a critical risk factor for future AUD above and beyond established risk factors. If this is the case, it will be important to determine whether some adolescents and young adults who engage in solitary alcohol use may be at particular risk to develop alcohol problems. Some studies have found that male (vs. female) adolescents and young adults are particularly likely to report solitary alcohol use (see Skrzynski and Creswell, 2020). This may indicate that solitary alcohol use is more normative and perhaps less indicative of future AUD risk in males (and conversely that young females who engage in solitary alcohol use may be especially likely to develop AUD). Such knowledge would aid in creating targeted intervention programs aimed at females who may be at particular risk of developing alcohol problems.

Here, using large national samples of US adolescents followed for 17 years, we investigated (1) whether adolescent (modal age [hereafter referred to simply as age] 18) and young adult (age 23/24) solitary alcohol use was concurrently associated with binge drinking after controlling for adolescent and young adult frequency of alcohol use, (2) whether adolescent and young adult solitary alcohol use prospectively predicted AUD symptoms in adulthood (age 35) after controlling for adolescent and young adult binge drinking and frequency of alcohol use, and (3) whether solitary alcohol use interacted with sex in associations with age 35 AUD symptoms to determine whether female adolescents and young adults who engage in solitary alcohol use are particularly

likely to develop alcohol problems in adulthood.

## 2. Methods

Analyses used data from the national cohort-sequential Monitoring the Future (MTF) study, which is an ongoing study of adolescents followed into adulthood in the US (for detailed methods, see Schulenberg et al., 2020). Annually since 1975, MTF has surveyed nationally-representative samples of approximately 15,000 12th grade students (modal age 18) from approximately 130 public and private schools in the contiguous US. Students usually complete the survey during a high school class period. Informed consent (active or passive, per school policy) was obtained from parents (if students were <18 years) or students (if students were  $\geq 18$  years). Approximately 2400 individuals are randomly selected from each cohort for follow-up. Half are randomly assigned to begin longitudinal follow-up one year later (age 19) and half two years later (age 20). Six biennial surveys are conducted (up through age 29/30), after which data collection occurs every five years (starting at age 35). A University of Michigan institutional review board approved the study. The hypotheses were not formally preregistered. Requests to access the data should be directed to the relevant archive (see <https://www.icpsr.umich.edu/web/NAHDAP/studies/37072/summary>).

### 2.1. Participants

The present analyses included adolescents from the 12th grade high school classes of 1976–2002 (12th grade response rates for these cohorts averaged 82.9%) (Miech et al., 2020). Age 23/24 (referred to hereafter as young adult) follow-up data were collected from 1981 to 2008; age 35 follow-up data were collected from 1993 to 2019 (see Supplement Table 1 for detailed information on cohorts). Multiple questionnaire forms were used to decrease respondent burden (randomly assigned at 12th grade); the solitary alcohol use measure was included on one form. A total of 11,791 12th grade students who responded to the form including the solitary use measure were selected for longitudinal follow-up. Of these, 5779 (49.0%) 12th graders responded at the age 35 follow-up. Attrition analyses indicated that participants who remained in the study at the age 35 follow-up were more likely to be female, White, and have at least one parent with a college degree; conversely those remaining in the study were less likely to report binge drinking or solitary alcohol use age at 18 (referred to hereafter as the adolescent time point). All 5779 respondents participated at age 18, and a total of 5339 (92.4% of the 5779) participated at age 23/24. As the solitary use item was asked only of alcohol users, eligible respondents were limited to those who reported drinking alcohol in the previous 12 months ( $n = 4802$  for the adolescent time point; 5235 for the young adult time point). After removal of cases with missing data on outcome measures (i.e., concurrent binge drinking at age 35 AUD symptoms), final sample sizes were 4464 (93.0% of 4802) for adolescent concurrent and prospective models and 4561 (87.1% of 5235) for young adult concurrent and prospective models. See Supplement Appendix A and Supplement Figure 1 for further details.

### 2.2. Measures

#### 2.2.1. Frequency of alcohol use

At the adolescent and young adult time points, participants were asked on how many occasions (if any) they had an alcoholic beverage during the last 12 months. Response options were as follows: 1 = 0 occasions, 2 = 1–2 occasions, 3 = 3–5 occasions, 4 = 6–9 occasions, 5 = 10–19 occasions, 6 = 20–39 occasions, 7 = 40+ occasions. For analysis, response values were recoded to the midpoints/upper end of the response options: 0, 0.5, 4.0, 7.5, 14.5, 29.5, and 40 occasions.

**Table 1**  
Sample Descriptive Statistics.

	Adolescent Models			Young Adult Models		
	% or Mean <sup>a</sup>	(SE) <sup>a</sup>	% Missing <sup>b</sup>	% or Mean <sup>a</sup>	(SE) <sup>a</sup>	% Missing <sup>b</sup>
Concurrent alcohol use measures						
Solitary alcohol use <sup>c</sup> (%)			0.6			0.4
None	72.6	(0.80)		59.8	(0.84)	
Any	27.4	(0.80)		40.2	(0.84)	
Past 12-month alcohol use frequency <sup>c</sup> (mean)	16.1	(0.25)	2.8	22.4	(0.26)	1.2
Binge drinking frequency <sup>c</sup> (mean)	1.1	(0.04)		1.0	(0.03)	
Covariates						
Sex			0.0			0.0
Female	51.1	(0.87)		51.9	(0.86)	
Male	48.9	(0.87)		48.1	(0.86)	
Race/ethnicity			0.1			1.0
Black	9.1	(0.68)		10.6	(0.72)	
Hispanic	5.2	(0.46)		5.5	(0.48)	
White	79.9	(0.86)		78.3	(0.86)	
Other	5.8	(0.49)		5.6	(0.43)	
Parental education			3.1			2.9
College degree	43.4	(0.86)		44.6	(0.85)	
Other	56.6	(0.86)		55.4	(0.85)	
Marital status (age 23/24)						0.1
Married	–			25.7	(0.74)	
Other	–			74.3	(0.74)	
College status (age 23/24)						0.9
4-year attendance/completion	–			51.8	(0.86)	
Other	–			48.2	(0.86)	

Notes: Ns (unweighted) = 4464 for adolescent (i.e., age 18) models, and 4561 for young adult (i.e., age 23/24) models. All estimates were weighted.

<sup>a</sup> Weighted estimates among cases with non-missing data.

<sup>b</sup> Unweighted percent of all cases with missing data on noted measure.

<sup>c</sup> Measured at noted time point (either during adolescence or young adulthood).

### 2.2.2. Binge drinking

At the adolescent and young adult time points, participants were asked how many times they had five or more drinks in a row over the last two weeks (response options: 1 = *none*, 2 = *once*, 3 = *twice*, 4 = *3–5 times*, 5 = *6–9 times*, 6 = *10 + times*). For analysis, response values were recoded to the midpoints/upper end of the response options: 0, 1, 2, 4, 7.5, and 10 times.

### 2.2.3. Solitary alcohol use

Solitary alcohol use was assessed among those who reported past 12-month alcohol use at the adolescent and young adult time points using the following question: “When you used alcohol during the last year, how often did you use it in each of the following situations?...When you were alone?” (response options: 1 = *not at all*, 2 = *a few of the times*, 3 = *some of the times*, 4 = *most of the times*, 5 = *every time*). Because the meaning of the response scale for past 12-month solitary alcohol use was

dependent on reported alcohol use frequency, a dichotomy of ever drinking alone (1) versus never (0) was coded for analyses.<sup>1</sup>

### 2.2.4. AUD symptoms

At age 35, participants were asked if they had used any alcohol in the past 5 years. If yes, they were instructed, “Think back over the last five years. Did your use of alcohol cause you any of the following problems?” For the years of data collection included in the current study, items addressing 8 of the 11 of the criteria for substance use disorder according to the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5)* (American Psychiatric Association [APA], 2013) were listed. Response options included the following: *no*, *a little*, *some*, *a lot* (see Supplemental Appendix B). To be consistent with prior published papers using MTF AUD symptom data, respondents were coded as exhibiting each criterion if they responded other than “no” to any item; the 8 dichotomous indicators were then summed to calculate the total number of criteria endorsed. Following recommended practice (APA, 2013; Goldstein et al., 2015; Grant et al., 2015), AUD symptoms were indicated by meeting two or more criteria. Respondents were coded as past-5-year abstainers (i.e., had not drank alcohol in the past 5 years), non-disordered drinkers (endorsed 0 or 1 criteria, thus drank alcohol but did not meet criteria for AUD symptoms), or having AUD symptoms (endorsed 2 + criteria) (Bray et al., 2019; Jang et al., 2018, 2019; Patrick et al., 2011; Patrick, Evans-Polce et al., 2021; Patrick and Terry-McElrath, 2021; Schulenberg et al., 2015). Because data were highly skewed, for analyses, a dichotomy was coded indicating AUD symptoms versus other.<sup>2</sup> AUD symptoms were further differentiated into mild (2–3 criteria), moderate (4–5 criteria), and severe (6 + criteria) categories. Although these measures of AUD symptoms do not yield a clinical diagnosis, the items are largely consistent with how alcohol and other drug use disorders have been measured in other large-scale surveys (Harford and Muthén, 2001; Muthén et al., 1993; Muthén, 1996; Nelson et al., 1998) and reflect symptoms of alcohol abuse and dependence in the *DSM-IV* (APA, 1996) and symptoms of AUD in the *DSM-5* (APA, 2013).

### 2.2.5. Sociodemographic covariates

Sex was coded as male or female (referent). Race/ethnicity was coded as White (referent), Black, Hispanic, or Other. Parent education (used as a proxy for socioeconomic status) indicated whether a college degree had been obtained by one or more parents versus neither parent (referent). Cohort was included using 7 dichotomous indicators (1976–79, 1980–83, 1984–87, 1988–91, 1992–95, 1996–99, 2000–02). For young adult models, additional covariates included concurrent marital status (married vs. other) and concurrent college education status (4-year college attendance or completion vs. other).

## 2.3. Data analysis

Descriptive analyses were conducted using survey procedures in SAS 9.4 (SAS Institute Inc., Cary, NC). Mplus 8.8 was used to fit models examining binge drinking frequency, disordered drinking likelihood, and AUD severity using the MLR estimator and Monte Carlo integration. Mplus utilizes full information maximum likelihood estimation, and thus uses all available data (Arbuckle, 1996; Enders, 2001). Missing data on covariates were addressed by including covariates in the model via modeling covariate variances (Muthén and Muthén, 2010). All analyses were weighted to adjust for both sampling and age 35 nonresponse using

<sup>1</sup> Models also were fit that included (a) continuous solitary use, (b) continuous 12-month alcohol frequency, and (c) an interaction of the two measures (as well as other covariates). Substantive results were unchanged from those reported in this paper.

<sup>2</sup> Additional models were run comparing AUD symptoms with non-disordered drinking only; conclusions were unchanged from those presented here.

an inverse-probability-weighting approach to correct for differential attrition (Weuve et al., 2012) based on extensive information available from 12th-grade measures including sex, race/ethnicity, region, number of parents in household, average parental education, religiosity, average high school grades, truancy, college plans, and substance use.

The purpose for Aim 1 (examining concurrent associations between adolescent and young adult solitary alcohol use and binge drinking frequency) was to provide background for Aim 2 (examining prospective associations between adolescent and young adult solitary alcohol use with AUD symptoms at age 35). Aim 1 models were conducted to examine if solitary alcohol use was significantly associated with binge drinking frequency at the adolescent and young adult time points. Separately for adolescents and young adults, multivariable negative binomial regression models regressed binge drinking frequency on solitary alcohol use controlling for alcohol use frequency and sociodemographic covariates. By controlling for alcohol use frequency, models allowed for estimation of the unique association between solitary alcohol use and binge drinking frequency net of total alcohol use among adolescents and young adults.

Aim 2 models were conducted to examine if, after controlling for alcohol use frequency and binge drinking frequency, solitary alcohol use during adolescence and young adulthood predicted age 35 AUD symptoms. Separate multivariable logistic regression (any AUD symptoms) and multinomial regression (AUD symptom severity) models were run for adolescents and young adults. By simultaneously including alcohol use frequency and binge drinking frequency with solitary alcohol use (as well as sociodemographic covariates), these models tested whether early solitary alcohol use accounted for unique variance in age 35 AUD symptoms above and beyond other early alcohol use risk factors.

For Aim 3, multivariable logistic regression models were run to test whether adolescent and young adult solitary alcohol use interacted with sex in predicting the likelihood of age 35 AUD symptoms. To probe significant interactions, subgroup specific models were run (i.e., we ran the prospective models separately for males vs. females).

### 3. Results

#### 3.1. Descriptive statistics

Table 1 presents descriptive statistics for the adolescent and young adult models. As shown, past year solitary alcohol use was reported by 27.4% of adolescents and 40.2% of young adults.

#### 3.2. Concurrent models

Table 2 shows the results of two negative binomial regression models for the concurrent (i.e., measured at the same age) associations between solitary alcohol use and binge drinking frequency in adolescents (Model 1) and young adults (Model 2), controlling for alcohol use frequency and sociodemographic covariates. Any solitary alcohol use was associated with a higher number of binge drinking occasions among both adolescents (Est. 0.27,  $p < .001$ ) and young adults (Est. 0.30,  $p < .001$ ).

#### 3.3. Prospective models

Table 3 displays the results of two logistic regression models predicting any age 35 AUD symptoms based on solitary alcohol use during adolescence (Model 1) and young adulthood (Model 2) after controlling for age-specific alcohol use frequency and binge drinking frequency, as well as other covariates. Among the cases in the adolescent model, 32.8% were classified as having AUD symptoms at age 35; among the cases in the young adult model, 31.1% were classified as having AUD symptoms at age 35. As can be seen, the multivariable odds of having any AUD symptoms at age 35 were 1.35 times higher for those reporting any solitary alcohol use during adolescence (see Model 1) and 1.60 times higher for those reporting any solitary alcohol use during young

**Table 2**

Multivariable associations between concurrent solitary alcohol use and the frequency of past 2-week binge drinking among adolescents and young adults.

	Model 1:	Model 2:
	Adolescents	Young Adults
	MEst. (SE) p	MEst. (SE) p
Any solitary alcohol use (vs. none) <sup>a</sup>	0.27 (0.06) < 0.001	0.30 (0.06) < 0.001
Past 12-month alcohol use frequency <sup>a</sup>	0.07 (0.002) < 0.001	0.07 (0.00) < 0.001
Male (vs. female)	0.46 (0.06) < 0.001	0.41 (0.06) < 0.001
Race/ethnicity (vs. White)		
Black	-0.36 (0.21) 0.089	0.10 (0.20) 0.618
Hispanic	-0.14 (0.17) 0.416	-0.01 (0.13) 0.935
Other	-0.19 (0.13) 0.149	-0.21 (0.12) 0.067
Parental college degree (vs. other)	-0.14 (0.06) 0.010	-0.08 (0.05) 0.124
Married (vs. other) <sup>b</sup>	–	-0.51 (0.08) < 0.001
College attendance/completion (vs. other) <sup>b</sup>	–	-0.23 (0.06) < 0.001
Cohort (vs. 2000–02)		
1976–79	-0.18 (0.14) 0.180	-0.31 (0.13) 0.022
1980–83	-0.05 (0.13) 0.717	-0.28 (0.14) 0.042
1984–87	-0.14 (0.14) 0.312	-0.17 (0.14) 0.228
1988–91	-0.18 (0.14) 0.212	-0.18 (0.13) 0.184
1992–95	0.06 (0.15) 0.690	-0.31 (0.14) 0.029
1996–99	-0.04 (0.15) 0.783	-0.16 (0.14) 0.224

Notes: Ns (unweighted) = 4464 for adolescent (i.e., age 18) models, and 4561 for young adult (i.e., age 23/24) models. MEst. = estimate from multivariable negative binomial regression models. SE = standard error. Separate models were run for adolescents and young adults.

<sup>a</sup> Measured at noted time point (either during adolescence or young adulthood).

<sup>b</sup> Measured at young adulthood (age 23/24).

adulthood (see model 2). Alcohol use frequency (but not binge drinking frequency) at the adolescent time point was an independent and significant predictor of age 35 AUD symptom likelihood; frequency of both alcohol use and binge drinking at the young adult time point were independent and significant predictors of age 35 AUD symptom likelihood.

As part of Aim 3, we tested for interactions between solitary alcohol use and sex in predicting age 35 AUD symptoms. Sex moderated adolescent solitary alcohol use (interaction term AOR 0.56,  $p = .001$ ) but not young adult solitary alcohol use (interaction term AOR 0.74,  $p = .070$ ). Sex-specific models indicated that female adolescent solitary alcohol users were at particular risk to develop age 35 AUD symptoms (AOR 1.86,  $p < .001$ ) compared to males (AOR 1.08,  $p = .525$ ).

#### 3.4. AUD symptom severity models

Tables 4 and 5 present results of multinomial logistic regression analyses wherein AUD symptoms were modeled as a four-level ordinal outcome (0 = non-disordered drinker, 1 = mild [2–3 criteria], 2 = moderate [4–5 criteria], or 3 = severe [6 + criteria]), regressed on adolescent and young adult solitary alcohol use and controlling for time point-specific alcohol use frequency and binge drinking frequency, as well as sociodemographic covariates. Non-disordered drinking was specified as the referent class. Adolescent (Table 4) and young adult (Table 5) solitary (vs. non-solitary) alcohol use generally was associated with higher AUD severity. Specifically, for adolescent solitary alcohol users, the odds of having mild and severe AUD symptoms (vs. non-disordered drinking) at age 35 were 1.37 and 1.59 times higher than adolescent non-solitary alcohol users, respectively (the comparison between moderate and non-disordered drinking was not significant; AOR 1.29,  $p = .052$ ). For young adult solitary alcohol users, the odds of having mild, moderate, and severe AUD symptoms (vs. non-disordered drinking) at age 35 were 1.33, 1.61, and 2.22 times higher than young adult non-solitary alcohol users, respectively.



**Table 3**

Prospective associations between adolescent and young adult solitary alcohol use and age 35 AUD symptoms after controlling for time point-specific 12-month alcohol use and 2-week binge drinking frequency.

	Model 1: Adolescents	Model 2: Young Adults
	AOR (95% CI) p	AOR (95% CI) p
Any solitary alcohol use (vs. none) <sup>a</sup>	1.35 (1.12, 1.62) 0.002	1.60 (1.34, 1.90) < 0.001
Past 12-month alcohol use frequency <sup>a</sup>	1.02 (0.97, 1.07) < 0.001	1.03 (1.03, 1.04) < 0.001
Binge drinking frequency (noted age) <sup>a</sup>	1.02 (1.02, 1.03) 0.419	1.23 (1.12, 1.30) < 0.001
Male (vs. female)	1.57 (1.34, 1.83) < 0.001	1.25 (1.05, 1.48) 0.013
Race/ethnicity (vs. White)		
Black	0.66 (0.42, 1.02) 0.061	0.76 (0.49, 1.17) 0.210
Hispanic	1.49 (0.99, 2.23) 0.056	1.28 (0.82, 2.00) 0.269
Other	0.70 (0.45, 1.07) 0.097	1.33 (0.90, 1.98) 0.154
Parental college degree (vs. other)	1.28 (1.09, 1.49) 0.002	0.96 (0.81, 1.19) 0.590
Married (vs. other) <sup>b</sup>	–	1.11 (0.91, 1.36) 0.317
College attendance/completion (vs. other) <sup>b</sup>	–	0.98 (0.83, 1.17) 0.839
Cohort (vs. 2000–02)		
1976–79	0.60 (0.43, 0.85) 0.004	0.58 (0.41, 0.83) 0.002
1980–83	0.51 (0.36, 0.72) < 0.001	0.58 (0.40, 0.82) 0.002
1984–87	0.51 (0.36, 0.73) < 0.001	0.59 (0.41, 0.85) 0.004
1988–91	0.66 (0.46, 0.95) 0.025	0.76 (0.53, 1.09) 0.131
1992–95	0.53 (0.36, 0.77) 0.001	0.57 (0.39, 0.84) 0.005
1996–99	0.78 (0.53, 1.15) 0.207	0.84 (0.56, 1.23) 0.360

Notes: Ns (unweighted) = 4464 for adolescent (i.e., age 18) models, and 4561 for young adult (i.e., age 23/24) models. AOR = adjusted odds ratio. CI = confidence interval. Separate models were run for adolescents and young adults.

<sup>a</sup> Measured at noted time point (either during adolescence or young adulthood).

<sup>b</sup> Measured at young adulthood (age 23/24).

**Table 4**

Prospective associations between adolescent solitary alcohol use and age 35 AUD symptom severity after controlling for adolescent 12-month alcohol use and 2-week binge drinking frequency.

	Mild (vs. non-disordered)	Moderate (vs. non-disordered)	Severe (vs. non-disordered)
	AOR (95% CI) p	AOR (95% CI) p	AOR (95% CI) p
Any solitary alcohol use (vs. none) <sup>a</sup>	1.37 (1.07, 1.77) 0.013	1.29 (1.00, 1.66) 0.052	1.59 (1.12, 2.25) 0.009
Past 12-month alcohol use frequency <sup>a</sup>	1.02 (1.01, 1.03) < 0.001	1.02 (1.01, 1.03) < 0.001	1.03 (1.02, 1.05) < 0.001
Binge drinking frequency <sup>a</sup>	1.02 (0.95, 1.08) 0.644	1.03 (0.97, 1.10) 0.359	1.04 (0.96, 1.11) 0.334
Male (vs. female)	1.36 (1.09, 1.70) 0.007	1.78 (1.44, 2.19) < 0.001	1.91 (1.40, 2.62) < 0.001
Race/ethnicity (vs. White)			
Black	0.59 (0.32, 1.09) 0.089	0.61 (0.31, 1.18) 0.142	1.07 (0.45, 2.52) 0.880
Hispanic	1.50 (0.88, 2.56) 0.137	1.33 (0.75, 2.33) 0.327	1.41 (0.66, 2.99) 0.375
Other	0.76 (0.42, 1.35) 0.346	0.73 (0.42, 1.27) 0.258	0.49 (0.22, 1.07) 0.074
Parental college degree (vs. other)	1.36 (1.10, 1.69) 0.005	1.27 (1.03, 1.56) 0.028	0.99 (0.74, 1.33) 0.933
Cohort (vs. 2000–02)			
1976–79	0.86 (0.54, 1.37) 0.525	0.59 (0.38, 0.94) 0.025	0.35 (0.19, 0.65) 0.001
1980–83	0.71 (0.44, 1.15) 0.163	0.49 (0.31, 0.78) 0.002	0.29 (0.15, 0.56) < 0.001
1984–87	0.58 (0.36, 0.94) 0.028	0.51 (0.32, 0.80) 0.004	0.40 (0.21, 0.76) 0.005
1988–91	0.90 (0.54, 1.48) 0.671	0.57 (0.35, 0.92) 0.020	0.51 (0.27, 0.97) 0.039
1992–95	0.58 (0.34, 0.98) 0.042	0.53 (0.32, 0.88) 0.014	0.38 (0.19, 0.77) 0.007
1996–99	1.02 (0.61, 1.72) 0.932	0.75 (0.45, 1.24) 0.264	0.47 (0.23, 0.94) 0.034

Notes: N (unweighted) = 4464. AOR = adjusted odds ratio. CI = confidence interval.

<sup>a</sup> Measured during adolescence.

#### 4. Discussion

Using large national samples of US adolescents followed for 17 years into adulthood, this study examined concurrent associations between adolescent (i.e., age 18) and young adult (i.e., age 23/24) solitary alcohol use and binge drinking, as well as prospective associations between adolescent and young adult solitary alcohol use and AUD symptoms at age 35. We predicted that solitary alcohol use in adolescence and young adulthood would be cross-sectionally associated with binge drinking, replicating prior findings linking solitary alcohol use to heavier concurrent alcohol consumption (Skrzynski and Creswell, 2020, 2021). In addition, we predicted that early solitary alcohol use would be a unique predictor of later AUD symptoms independent of its associations with concurrent binge drinking and other risk factors (e.g., frequency of alcohol use, male sex).

We found strong support for both hypotheses. Results showed associations between adolescent and young solitary alcohol use and concurrent binge drinking, suggesting that solitary alcohol use accounts for unique variance in concurrent binge drinking beyond overall alcohol use frequency and sociodemographic characteristics. These results suggest that solitary alcohol use is a unique predictor of binge drinking not simply because of a higher frequency of alcohol use in young adulthood.

Importantly, adolescent and young adult solitary alcohol use prospectively predicted AUD symptoms in adulthood (age 35) above and beyond other established early risk factors including adolescent and young adult alcohol use frequency and binge drinking frequency and sociodemographic characteristics. Specifically, the odds of AUD symptoms at age 35 was 35% higher for adolescent solitary (vs. non-solitary) alcohol users, and 60% higher for young adult solitary (vs. non-solitary) alcohol users. Adolescent and young adult solitary (vs. non-solitary) alcohol use was also associated with higher AUD severity at age 35. For instance, the likelihood of reporting severe AUD symptoms (vs. non-disordered drinking) at age 35 was 59% higher for adolescent solitary (vs. non-solitary) alcohol users and more than two times as high for young adult solitary (vs. non-solitary) alcohol users. These findings replicate prior studies demonstrating a prospective link between adolescent and young adult solitary alcohol use and subsequent alcohol problems, but prior studies used relatively small sample sizes that were restricted to certain geographical regions in the US (Creswell et al., 2014; Tucker et al., 2006; Waddell et al., 2021). Results from this large national sample of adolescents followed into adulthood provide compelling evidence that solitary alcohol use during adolescence and young adulthood may be a critical risk factor for the development of

Table 5

Prospective associations between young adult solitary alcohol use and age 35 AUD symptom severity after controlling for young adult 12-month alcohol use and 2-week binge drinking frequency.

	Mild (vs. non-disordered)	Moderate (vs. non-disordered)	Severe (vs. non-disordered)
	AOR (95% CI) p	AOR (95% CI) p	AOR (95% CI) p
Any solitary alcohol use (vs. none) <sup>a</sup>	1.33 (1.01, 1.69) 0.016	1.61 (1.27, 2.06) < 0.001	2.22 (1.53, 3.22) < 0.001
Past 12-month alcohol frequency <sup>a</sup>	1.02 (1.02, 1.03) < 0.001	1.04 (1.03, 1.05) < 0.001	1.03 (1.01, 1.05) < 0.001
Binge drinking frequency <sup>a</sup>	1.15 (1.08, 1.23) < 0.001	1.26 (1.18, 1.34) < 0.001	1.34 (1.24, 1.46) 0.001
Male (vs. female)	1.29 (1.02, 1.63) 0.032	1.25 (0.99, 1.57) 0.056	1.31 (0.92, 1.85) 0.130
Race/ethnicity (vs. White)			
Black	0.62 (0.32, 1.20) 0.159	0.68 (0.35, 1.34) 0.269	1.70 (0.85, 3.41) 0.133
Hispanic	1.36 (0.78, 2.46) 0.301	1.13 (0.60, 2.14) 0.708	1.41 (0.66, 3.00) 0.377
Other	1.31 (0.79, 2.20) 0.299	1.39 (0.81, 2.40) 0.234	1.08 (0.51, 2.30) 0.836
Parental college degree (vs. other)	1.04 (0.83, 1.30) 0.735	0.92 (0.73, 1.15) 0.454	0.81 (0.58, 1.14) 0.226
Married (vs. other)	1.00 (0.75, 1.33) 0.988	1.14 (0.88, 1.49) 0.320	1.18 (0.79, 1.78) 0.414
College attendance/completion (vs. other)	1.07 (0.85, 1.35) 0.565	0.92 (0.73, 1.16) 0.490	0.76 (0.54, 1.08) 0.124
Cohort (vs. 2000–02)			
1976–79	0.96 (0.60, 1.52) 0.851	0.54 (0.34, 0.86) 0.010	0.30 (0.18, 0.53) < 0.001
1980–83	0.92 (0.58, 1.47) 0.724	0.53 (0.33, 0.85) 0.009	0.28 (0.15, 0.50) < 0.001
1984–87	0.77 (0.47, 1.26) 0.300	0.58 (0.36, 0.93) 0.024	0.34 (0.19, 0.63) 0.001
1988–91	1.06 (0.65, 1.75) 0.809	0.65 (0.39, 1.07) 0.088	0.52 (0.29, 0.92) 0.023
1992–95	0.92 (0.55, 1.53) 0.737	0.51 (0.30, 0.88) 0.016	0.28 (0.14, 0.56) < 0.001
1996–99	1.25 (0.74, 2.12) 0.407	0.80 (0.48, 1.33) 0.380	0.40 (0.21, 0.74) 0.004

Notes: N (unweighted) = 4340. AOR = adjusted odds ratio. CI = confidence interval.

<sup>a</sup> Measured during young adulthood.

alcohol problems in adulthood over and above other established risk factors.

Female adolescents who drank alone were at particular risk of developing later AUD symptoms. This finding is noteworthy given recent increases in solitary alcohol use among female adolescents (Terry-McElrath et al., 2021), and is consistent with two recent papers showing relatively stronger associations between solitary alcohol use and alcohol-related problems in females compared to males (Corbin et al., 2020; Waddell et al., 2021). Taken together, these findings suggest that the negative impact of solitary alcohol use may be particularly robust for females and indicate that targeted interventions may be especially useful for female solitary alcohol users.

Adolescents and young adults who report solitary alcohol use appear to do so primarily to cope with negative emotions (Creswell, 2021; Creswell, Chung, Wright et al., 2015; Mason et al., 2020; Mohr et al., 2001; Skrzynski and Creswell, 2020; Skrzynski et al., 2021), a pattern of alcohol use that has been consistently linked to the development of alcohol problems (Creswell et al., 2020; Crum et al., 2013; Patrick et al., 2011). Indeed, recent work shows that drinking to cope with negative emotions mediates the longitudinal association between solitary alcohol use and alcohol problems in a sample of US young adults (Waddell et al., 2021). Future work is indicated to determine whether the prospective link found here between early solitary alcohol use and later alcohol problems is accounted for by drinking to cope motives. Finally, it is important to note that the current study demonstrates that approximately one quarter of adolescent drinkers and 40% of young adult drinkers reported solitary alcohol use in the past year (cf. Mason et al., 2020; Skrzynski and Creswell, 2020; Terry-McElrath et al., 2021), which suggests that a substantial portion of young people who use alcohol are drinking alone in the US.

Important strengths of this study include the use of large national samples of adolescents followed for nearly two decades. This study also has limitations. First, alcohol use and problems were assessed by self-report. Second, in the MTF study, symptoms of AUD are not assessed until age 35, so we were unable to control for adolescent and early young adult AUD symptoms in our models. We did however control for earlier binge drinking and frequency of alcohol use in our prospective analyses, which are highly correlated with AUD symptoms (Creswell et al., 2020; Merline et al., 2008; Patrick et al., 2011; Schulenberg et al., 2015). Third, AUD symptoms at age 35 were assessed over a 5-year period, which is a longer time period than some standard measures. Future studies that use objective measures of alcohol use (e.g.,

transdermal alcohol monitoring; Fairbairn and Kang, 2021) and/or corroborating reports from informants, as well as ones that assess AUD symptoms at baseline and AUD symptoms over a 12-month period at follow-up, are needed. Fourth, we used a threshold for determining each specific AUD criterion cutoff in accordance with prior analyses using MTF AUD symptom data (*a little/some/a lot vs. none*); this approach yields an estimate of the prevalence of those with AUD symptoms, not AUD diagnosis. However, we followed recommended guidelines when identifying the number of criteria associated with AUD symptoms and related severity (APA, 2013; Goldstein et al., 2015; Grant et al., 2015). Finally, solitary use of other drugs has also been linked to negative outcomes (e.g., Creswell, Chung, Clark, and Martin, 2015; Mason et al., 2020), and future studies should continue to explore the role of solitary polysubstance use in predicting substance use disorder symptoms and other negative outcomes.

The COVID-19 pandemic has exacerbated problematic alcohol use for many individuals (Pollard et al., 2020; Rehm et al., 2020), possibly due to increases in negative affect and drinking to cope with pandemic-related distress (Buckner et al., 2021; Creswell and Bachrach, 2020; Graupensperger et al., 2021; Lechner et al., 2021). Notably, the COVID-19 pandemic gave rise to widespread restrictions (e.g., bar closures) and stay-at-home directives, which caused drastic changes for young adults in the typical context of their alcohol consumption (e.g., less drinking in bars with others and more drinking at home) (Irizar et al., 2021; Patrick et al., 2022). These changes may have led to recent increases in adolescent and young adult solitary alcohol use and concomitant increases in alcohol problems. Identifying and responding to early risk factors for alcohol misuse is essential in order to prevent the development of AUD. Adolescent and young adult solitary alcohol use may be a “red flag” indicative of emerging addictive pathology (i.e., using alcohol to cope with negative emotions) that warrants early intervention (Creswell, 2021; Knight et al., 1999). Our findings highlight the need to go beyond only asking about how much and how frequently young people drink to include additional evaluation of whether or not they drink alone. Understanding solitary alcohol use in young people may be critical for effective screening and intervention efforts to reduce AUD.

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## Contributors

K.C. and M.P. developed the study concept. Y.T. performed the data analysis. K.C. drafted the manuscript, and M.P. and Y.T. provided critical revisions. All authors approved the final version of the manuscript for submission.

## Conflict of Interest

No conflict declared.

## Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.drugalcdep.2022.109552](https://doi.org/10.1016/j.drugalcdep.2022.109552).

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