



# Solitary cannabis use in adolescence as a correlate and predictor of cannabis problems

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## ABSTRACT

**Background:** Most adolescent cannabis use occurs in social settings among peers. Solitary cannabis use during adolescence may represent an informative divergence from normative behavior with important implications for understanding risk for cannabis problems. This longitudinal study examined associations of adolescent solitary cannabis use with levels of cannabis use and problems in adolescence and in young adulthood.

**Methods:** Cannabis using-adolescents aged 12–18 were recruited from clinical programs ( $n = 354$ ; 43.8% female; 83.3% Caucasian) and community sources ( $n = 93$ ; 52.7% female; 80.6% Caucasian). Participants reported on cannabis use patterns and diagnostic symptoms at baseline and multiple follow-ups into young adulthood.

**Results:** Compared to social-only users, adolescent solitary cannabis users were more likely to be male and reported more frequent cannabis use and more DSM-IV cannabis use disorder (CUD) symptoms. Regression analyses showed that solitary cannabis use in adolescence predicted CUD symptom counts in young adulthood (age 25) after controlling for demographic variables and the frequency of adolescent cannabis use. However, solitary adolescent cannabis use was no longer predictive of age 25 CUD symptoms after additionally controlling for adolescent CUD symptoms.

**Conclusions:** Solitary cannabis use is associated with greater cannabis use and problems during adolescence, but evidence is mixed that it predicts young adult cannabis problems.

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## 1. Introduction

Regular cannabis use among US adolescents has been increasing since 2007, with 21% of high school seniors reporting past month use and close to 6% reporting daily use (Johnston et al., 2015). Cannabis use that begins in adolescence increases the risk of developing cannabis problems later in life (Anthony, 2006; Hall and Degenhardt, 2009; Silins et al., 2014). It is therefore important to identify early occurring risk factors that predict later cannabis-related problems.

Most cannabis use occurs in social settings (Buckner et al., 2012, 2013), and this is particularly true for adolescent cannabis use. For instance, in the *Monitoring the Future Study*, approximately 90% of high school seniors who used only cannabis in the past year reported doing so in social settings (McCabe et al., 2014). Little work

has examined solitary cannabis use among adolescents, which may indicate a divergence from normative behavior with important implications for understanding risk for cannabis problems. Prior studies have shown that solitary, compared to social-only, alcohol use among adolescents and young adults is associated with poor psychosocial and behavioral problems (Christiansen et al., 2002; Gonzalez et al., 2009; Gonzalez and Skewes, 2013; Mohr et al., 2001; Tucker et al., 2006). For instance, we recently reported that adolescent solitary alcohol use is associated with heavier drinking in adolescence and predicts alcohol problems in young adulthood even after controlling for adolescent alcohol use and problems (Creswell et al., 2014).

Among young adults, cross sectional studies have shown a robust association between solitary cannabis use and symptoms of DSM-IV Cannabis Use Disorder (CUD). For instance, in a study of 521 young adult frequent cannabis users, solitary use “most of the time” (yes/no) was the only cannabis use variable that distinguished individuals with DSM-IV cannabis dependence from non-dependent users (van der Pol et al., 2013). Similarly, among 843 students from German universities who reported current cannabis use, using

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cannabis while alone (as the “usual context” of use) was one of the strongest predictors of DSM-IV cannabis dependence (Noack et al., 2011).

We are aware of only one prior study that has examined whether solitary cannabis use in adolescence prospectively predicts drug problems in young adulthood. Tucker et al. (2006) compared eighth-grade adolescents who endorsed ever having used cannabis when alone ( $n = 148$ ) to those who only used cannabis in social settings ( $n = 388$ ). During eighth grade, solitary users reported more frequent cannabis use, held more positive cannabis reinforcement expectancies, earned poorer grades, and engaged in more deviant behaviors than students who used cannabis only in social settings. Furthermore, eighth grade solitary users, compared to social-only users, were more likely to endorse a single dichotomous item assessing drug problems at age 23 (i.e., use of any drug that negatively affected finances, home life, work life, relationships, or legal status) even after accounting for eighth grade cannabis use.

The current research extends the Tucker et al. (2006) study by studying adolescent solitary cannabis use patterns in more detail and examining their association with DSM-IV CUD symptoms in adolescence and young adulthood (age 25). We hypothesized that (1) adolescent solitary cannabis users would have a greater frequency of cannabis use and more CUD symptoms compared to social-only adolescent users, and (2) solitary cannabis use in adolescence would predict CUD symptoms in young adulthood even when controlling for demographics and the frequency of cannabis use and CUD symptoms during adolescence.

## 2. Methods

### 2.1. Participants

Participants included 447 adolescents recruited from clinical and community sources first seen between the ages of 12 and 18 years (mean age = 16.2,  $SD = 1.5$ ) participating in a longitudinal study at the Pittsburgh Adolescent Alcohol Research Center (PAARC). The use of clinical and community recruits provides a sample with a broad range of cannabis involvement. Details regarding recruitment procedures have been published previously (e.g., Clark et al., 2001a,b, 2010; Maisto et al., 2002). Exclusion criteria included psychosis, mental retardation, and a history of serious neurological disturbance, as indicated by parent self-report during an initial phone screen. Clinical participants ( $n = 354$ ; 155 females, 199 males) were recruited from a wide variety of clinical programs in the Pittsburgh area, including hospital-based out-patient and in-patient addictions and dual diagnosis programs, free-standing programs that provided treatment for addictions and behavioral problems, and residential programs for youth with family difficulties. All of these locations provided addictions treatment. These participants were identified through a recruiter who presented information about the study to family groups or through therapists who obtained “consent to contact” the family. Of the clinical participants who provided consent to contact, 73% passed a screen for eligibility and completed the baseline assessment. Clinical adolescents who did and did not complete the screen and the baseline assessment did not differ in demographic characteristics (Maisto et al., 2002). The clinical sample is quite similar in demographic and clinical characteristics to Caucasians and African American adolescents in nationally representative addiction treatment samples [e.g., the Drug Abuse Treatment Outcome Studies for Adolescents (DATOS-A) sample (Kristiansen and Hubbard, 2001) and the Substance Abuse and Mental Health Services Administration’s (SAMHSA’s) national Treatment Episode Data set (TEDS; SAMHSA, 2006)]. This comparability to two large national treatment samples strongly suggests that our clinical sample is broadly representative of adolescents who receive addictions treatment from a wide variety of clinical programs. Community participants ( $n = 93$ ; 49 females, 44 males) were recruited from community sources, including marketing and survey sampling databases or advertisements, flyers, and word of mouth approaches.

The current sample is comprised of participants who reported cannabis use during adolescence ( $n = 625$ ) and who also had data available at an age 25 follow-up visit ( $n = 447$ ).<sup>1</sup> Participants who missed the young adult assessment, compared with those who completed the visit, were more likely to be male (69.7% vs. 54.4%;

$\chi^2 = 12.3$ ,  $df = 1$ ,  $p < .001$ ) and non-Caucasian (28.1% vs. 17.2%;  $\chi^2 = 9.3$ ,  $df = 1$ ,  $p = .002$ ), and were more likely to have been recruited from the community (31.5% vs. 20.8%;  $\chi^2 = 7.9$ ,  $df = 1$ ,  $p = .005$ ). There were no differences in the peak number of CUD symptoms during adolescence between those who missed the young adult assessment and those who completed it ( $4.4 \pm 3.1$  vs.  $4.9 \pm 2.9$ ;  $F = 3.4$ ,  $df = 1$ ,  $p = .07$ ). The sample used in this report was 82.8% Caucasian, 17.0% African American, and less than 1% other racial/ethnic backgrounds.

### 2.2. Procedures

Participants were initially assessed between the ages of 12 and 18. Measures included lifetime drug use, substance use disorders and other psychopathology, health status, and other variables. Similar measures were used for the 1-, 3-, 5-year, and age 25 follow-up assessments, all of which covered the interval since the last completed assessment. We used all assessments (baseline and follow-ups) conducted through age 18 to characterize solitary cannabis use during adolescence. Data from the age 25 assessment were used to determine young adult outcomes. Participants were paid \$125 in gift certificates for completing each assessment. The study was approved by the University of Pittsburgh IRB. Written informed consent was obtained from a parent for a minor’s participation; participants provided assent (or consent when age  $\geq 18$ ).

### 2.3. Measures

**2.3.1. Demographics.** Adolescent demographic characteristics, collected at the baseline assessment, included gender, race/ethnicity, and socio-economic status (SES) as indicated by the Hollingshead Two-Factor Index (Hollingshead, 1975).

**2.3.2. Adolescent cannabis use and solitary cannabis use.** Cannabis use frequency and solitary versus social-only cannabis use were measured by a version of the Lifetime Drinking History (Skinner and Sheu, 1982), which was adapted to assess cannabis use patterns among adolescents (Clark et al., 2001b). Participants reported cannabis use frequency (days per month) and percentage of time that their cannabis use occurred while alone versus with others (on a 0–100% scale). Since solitary cannabis use was assessed as a percentage of total use episodes, rather than as a count of solitary use occurrences, we avoided the confound of greater frequency of cannabis use being associated with both social and solitary use contexts. At the baseline assessment, cannabis use data were retrospectively recalled for each year since the start of cannabis use. For subsequent assessments (i.e., at 1-, 3-, and 5-year follow-up), cannabis use data were collected for each year since the last completed assessment.

**2.3.3. Adolescent and young adult DSM-IV CUD symptoms.** Information about past-year adolescent and young adult CUD symptoms and diagnoses were collected using the Structured Clinical Interview for DSM-IV (SCID; First et al., 2002; Martin et al., 1995, 2000). Interviewers had master’s-level education in mental health-related fields and were trained to obtain high agreement with an experienced interviewer (see Martin et al., 2000).

### 2.4. Data analyses

Consistent with our approach to measuring adolescent solitary alcohol use (see Creswell et al., 2014), we used three summary variables to measure adolescent solitary cannabis use through age 18: maximum percentage of time smoking cannabis alone (Alone-Max), mean percentage of time smoking cannabis alone (Alone-Mean), and a binary variable of ever having smoked cannabis alone [Alone-Ever (yes/no)].

We first examined rates of solitary use across ages 12–18 and the characteristics of adolescent solitary users. Next, we computed bivariate correlations of the three adolescent solitary cannabis use variables with adolescent frequency of cannabis use and CUD symptom counts, and young adult CUD symptom counts. Separate hierarchical linear regression analyses were then used to predict CUD symptom counts in young adulthood from each of the three adolescent solitary cannabis use variables. For these analyses, young adult past year CUD symptom count was regressed hierarchically on three sets of independent variables, which were entered in the following order: step 1 = gender, race/ethnicity, and SES; step 2 = cannabis frequency during adolescence, and step 3 = solitary cannabis use. In another hierarchical regression analysis, which represented a very strict test of the predictive power of adolescent solitary use, we added another predictor at step two: adolescent CUD symptom count.

social only users of both substances). In addition, there were 27 cannabis users (6.1%; 12 solitary and 15 social-only) who had missing data for solitary alcohol use because they did not engage in regular alcohol use and thus were not asked about solitary alcohol use. We did not control for solitary drinking in our analyses given the large overlap of participants who endorsed solitary use of both alcohol and cannabis (see also Tucker et al., 2006). Solitary alcohol use in adolescence (yes/no) was not related to subsequent problems with cannabis ( $r = 0.04$ ,  $p = .36$ ).

<sup>1</sup> Most participants (96.2%) in the current study were included in our prior report on solitary drinking (Creswell et al., 2014). Examination of the data revealed that, of the 447 participants, approximately 35% ( $n = 154$ ) endorsed solitary use of both alcohol and cannabis, 27.5% ( $n = 123$ ) were solitary cannabis users but not solitary drinkers, 6% ( $n = 28$ ) were solitary drinkers but not solitary cannabis users, and 25.7% ( $n = 115$ ) were neither solitary cannabis users nor solitary drinkers (i.e., they were

**Table 1**  
Percentage of adolescents reporting any solitary cannabis use and mean percentage of time spent using cannabis while alone for each age across the adolescent period.

Measure	Age (years)						
	12	13	14	15	16	17	18
<i>n</i>	33	81	168	252	315	325	310
Adolescents reporting any solitary cannabis use (%)	30.3	38.3	36.9	43.2	46.0	51.7	53.5
Solitary cannabis use episodes for solitary users only, mean % (SD) <sup>a</sup>	31.5 (26.6)	27.6 (24.7)	22.3 (18.1)	25.9 (21.3)	29.9 (21.0)	31.1 (22.9)	30.0 (20.5)
Range in % of solitary cannabis use episodes reported	0–100	0–100	0–80	0–100	0–100	0–100	0–100

Note: Sample size at each age represents the number of youth who reported cannabis use at that age on the Lifetime Drinking History measure. Data at each age includes initial session and/or follow-up data within the adolescent time period.

<sup>a</sup> *n* = 289.

**Table 2**  
Demographic characteristics and cannabis use variables of adolescents who did versus did not engage in solitary cannabis use.

Characteristic and variable	Solitary Users		Social-only Users		$\chi^2$	<i>F</i>	<i>p</i>	Effect size
	<i>n</i> /Mean	%/SD	<i>n</i> /Mean	%/SD				
Gender								
Male	177	61.2	66	41.8	15.6		<.001	Phi = .19
Female	112	38.8	92	58.2				
Race/ethnicity <sup>a</sup>								
Caucasian	235	81.3	135	85.4	1.2		0.27	Phi = .05
African American	54	18.7	23	14.6				
SES	37.6	12.3	36.9	12.6		.31	0.58	$\eta_p^2 = .00$
Recruitment source								
Clinical	255	72.0	99	28.0	40.6		<.001	Phi = .30
Community	34	36.6	59	63.4				
Adolescent cannabis use days per month <sup>b</sup>	9.2	6.1	3.9	4.2		97.9	<.001	$\eta_p^2 = .18$
Adolescent CUD symptoms <sup>b</sup>	2.5	1.5	.96	1.1		120.4	<.001	$\eta_p^2 = .21$

Note: CUD = cannabis use disorder; SES = socioeconomic status.

<sup>a</sup> Only one individual did not self-identify as either Caucasian or African American, and was not included in this analysis.

<sup>b</sup> Values represent averages across ages 12–18. Separate tests were also run for each age group, and the significant results above remained significant at all ages. Results (not shown) did not change when gender and recruitment source were entered as covariates in these analyses.

### 3. Results

#### 3.1. Descriptive and cross-sectional results

Of the 447 participants, 289 (64.7%) reported smoking cannabis alone at least once during adolescence, and 158 (35.3%) reported cannabis use only in social settings through age 18. Across ages 12–18, more than 3/4 of the sample remained stable in their endorsement of solitary cannabis use (i.e., either consistently reporting or not reporting solitary use). Less than 1/4 showed a pattern of no solitary cannabis use at younger ages followed by solitary use at older ages. Table 1 shows the percentage of adolescents at ages 12–18 years reporting any solitary cannabis use and the mean percentage of solitary use episodes among solitary users. As shown, the percentage of adolescents engaging in solitary use increased with age. Among solitary adolescent users, this behavior remained fairly stable over time.

Table 2 shows descriptive characteristics of adolescents who reported any solitary cannabis use in adolescence (solitary users) compared to those who used cannabis only in social

situations (social-only users). The majority of the clinical participants reported solitary cannabis use; community participants were less likely to endorse this behavior. Compared to social-only users, solitary cannabis users were more likely to be male and reported more frequent cannabis use and more past year CUD symptoms through age 18. Solitary cannabis use in adolescence did not differ by race/ethnicity. Table 3 shows the Pearson product-moment correlations between the three adolescent solitary cannabis use variables and adolescent frequency of cannabis use, adolescent CUD symptom counts, and young adult CUD symptom counts. As shown, adolescent solitary cannabis use was positively correlated with adolescent cannabis use and cannabis problems during adolescence and young adulthood.

#### 3.2. Solitary Cannabis Use in Adolescence and Young Adult Cannabis Use Disorder Symptoms

Forty-four percent of young adults (*n* = 195) had at least one past-year DSM-IV CUD symptom at age 25 (full sample *M* = 1.72,

**Table 3**  
Pearson product-moment correlations between adolescent solitary cannabis use, adolescent frequency of cannabis use, adolescent CUD symptom counts, and young adult CUD symptom counts (*n* = 447).

	Alone-Max	Alone-Ever	Alone-Mean	Frequency of cannabis use at age 18 <sup>a</sup>	CUD symptoms at age 18 <sup>a</sup>	Age 25 CUD symptoms
Alone-Max	1.00					
Alone-Ever		.638***				
Alone-Mean			1.00			
Adolescent frequency of cannabis use				1.00		
Adolescent CUD symptoms					1.00	
Age 25 CUD symptoms						1.00

Note: CUD = cannabis use disorder. Alone-Max = maximum percentage of time smoking cannabis alone during the ages of 12–18. Alone-Ever = a binary variable of ever having smoked alone during the ages of 12–18 (0 = no, 1 = yes). Alone-Mean = mean percentage of time smoking cannabis alone during the ages of 12–18.

<sup>a</sup> Age 18 data were used because this was the age of heaviest mean cannabis use during adolescence.

\*\* *p* < .01.

\*\*\* *p* < .001.

**Table 4**  
Hierarchical regression analysis predicting age 25 CUD symptoms.

Variable	$\beta$	<i>t</i>	<i>R</i>	<i>R</i> <sup>2</sup>	$\Delta R^2$	$\Delta F$
Step 1			.34	.11	.11	18.17***
Gender	.24	5.32***				
Ethnicity	.23	4.93***				
SES	−.06	−1.39				
Step 2			.37	.14	.03	14.12***
Cannabis frequency at age 18 <sup>a</sup>	.17	3.76***				
Step 3 <sup>b</sup>						
Alone-Max	.10	2.11*	.39	.15	.01	4.43*
Alone-Ever	.10	2.02*	.39	.14	.01	4.07*
Alone-Mean	.05	1.03	.38	.14	.00	1.06

Note. CUD = Cannabis use disorder. Alone-Max = maximum percentage of time smoking cannabis alone during the ages of 12–18. Alone-Ever = a binary variable of ever having smoked alone during the ages of 12–18 (0 = no, 1 = yes). Alone-Mean = mean percentage of time smoking cannabis alone during the ages of 12–18. Betas reported are those from the step at which the variable was entered into the equation.

<sup>a</sup> Separate regressions were also run entering cannabis frequency data for all other adolescent ages (i.e., ages 12–17) in Step 2. Solitary cannabis use remained a significant predictor (all *ps* < .03) at Step 3 in all analyses for Alone-Max and Alone-Ever.

<sup>b</sup> A separate regression analysis was performed with each of the three solitary cannabis use variables for step 3.

\* *p* < .05.

\*\*\* *p* < .001.

SD = 2.40; range 0–10). Table 4 shows the hierarchical regression results predicting age 25 CUD symptoms from three sets of predictors. In the first step, we entered demographic covariates and observed a statistically significant relationship between age 25 CUD symptoms and both male gender and African American race/ethnicity. In the second step, we observed a significant relationship between higher frequency of age 18 cannabis use and more age 25 CUD symptoms. In the third step (in two separate analyses), the Alone-Max and Alone-Ever measures accounted for unique proportions of the remaining variance in age 25 CUD symptoms, but the effect sizes were small. The Alone-Mean solitary cannabis use measure, however, failed to account for a unique proportion of the remaining variance in step 3.<sup>2</sup>

Next, we conducted similar regression analyses but added adolescent CUD symptom counts as a predictor variable in step 2 (see Table 5). Adolescent symptom count was a strong predictor of young adult CUD symptom count. As such, controlling for the variance accounted for by adolescent cannabis problems provides a very strict test of whether adolescent solitary use predicts young adult CUD symptoms. In these analyses, none of the adolescent solitary cannabis use variables remained significant in step 3 (all *ps* > .16).

#### 4. Discussion

This is one of the first studies to examine cross-sectional and longitudinal associations of adolescent solitary cannabis use with measures of adolescent and young adult cannabis involvement. The past year solitary cannabis use estimates of 30–53% across ages 12–18 in this study are somewhat higher than rates reported in school-based studies (Tucker et al., 2006; McCabe et al., 2014),

<sup>2</sup> We also ran the hierarchical regression analyses predicting age 25 cannabis problems from adolescent solitary cannabis use with the additional covariates of adolescent depression (i.e., major depressive disorder or dysthymia) and anxiety (i.e., generalized anxiety disorder, panic disorder, or social phobia) diagnoses (yes/no) entered at step 2 (in addition to adolescent cannabis use frequency). These diagnoses were determined with the Kiddie Schedule for Affective Disorders and Schizophrenia-Present and Lifetime version (K-SADS), a semistructured interview for DSM-IV psychiatric disorders in youth and young adults (Kaufman et al., 1997; Puig-Antich and Chambers, 1978). Solitary cannabis use in adolescence (both Alone-Max and Alone-Ever) remained significant predictors of age 25 cannabis problems at step 3 after controlling for adolescent depression and anxiety (for Alone-Max *p* = .03; for Alone-Ever *p* = .04).

**Table 5**  
Hierarchical regression analysis predicting age 25 CUD symptoms controlling for adolescent CUD symptoms.

Variable	$\beta$	<i>t</i>	<i>R</i>	<i>R</i> <sup>2</sup>	$\Delta R^2$	$\Delta F$
Step 1			.34	.11	.11	18.17***
Gender	.24	5.32***				
Ethnicity	.23	4.93***				
SES	−.06	−1.39				
Step 2			.43	.19	.07	19.30***
Cannabis frequency at age 18 <sup>a</sup>	.05	0.96				
CUD symptoms at age 18	.26	4.87***				
Step 3 <sup>b</sup>						
Alone-Max	.07	1.43	.44	.19	.01	2.03
Alone-Ever	.06	1.24	.43	.19	.00	1.53
Alone-Mean	.03	0.57	.43	.19	.00	0.33

Note. CUD = Cannabis use disorder. Alone-Max = maximum percentage of time smoking cannabis alone during the ages of 12–18. Alone-Ever = a binary variable of ever having smoked alone during the ages of 12–18 (0 = no, 1 = yes). Alone-Mean = mean percentage of time smoking cannabis alone during the ages of 12–18. Betas reported are those from the step at which the variable was entered into the equation.

<sup>a</sup> Separate regressions were also run entering CUD symptom data for all other adolescent ages (i.e., ages 12–17) in Step 2. Solitary cannabis was not a significant predictor (all *ps* > .05) at Step 3 in any of the analyses for Alone-Max, Alone-Ever, or Alone-Mean.

<sup>b</sup> A separate regression analysis was performed with each of the three solitary cannabis use variables for step 3.

\*\*\* *p* < .001.

which may be due to the fact that our sample consisted mostly of adolescents recruited from clinical settings. In general, the context of cannabis use (i.e., solitary versus social) was relatively stable across adolescence in our sample, with the majority of adolescents either consistently reporting or not reporting solitary use. We also found that males were more likely to report adolescent solitary cannabis use than females. This is consistent with one prior study that found solitary cannabis use to be more prevalent among male than female young adults (Noack et al., 2011), but inconsistent with prior studies in adolescents that have either found no gender differences in solitary cannabis use (Tucker et al., 2006) or greater solitary use among females than males (Tucker et al., 2014). Discrepancies in the literature on gender differences in solitary marijuana use may be due to differences in sample characteristics, as the findings reported by Tucker et al. (2006, 2014) were from adolescents recruited from middle schools rather than young adults recruited from the community (Noack et al., 2011) or adolescents largely recruited from clinical settings (as in the current report).

As hypothesized, cross-sectional analyses indicated that adolescent solitary users had more frequent cannabis use and more DSM-IV CUD symptoms compared to adolescents who used only in social settings. These results replicate and extend findings reported by Tucker et al. (2006) to show that adolescent solitary users not only have greater cannabis use but also more cannabis use problems as defined by the DSM-IV. Our results are also consistent with cross-sectional studies linking solitary cannabis use in young adults to CUD (van der Pol et al., 2013; Noack et al., 2011).

This is the first study to test whether solitary cannabis use in adolescence predicts CUD symptoms in young adulthood. In partial support of this hypothesis, any solitary adolescent marijuana use, as well as a measure of the maximum proportion of solitary use episodes in adolescence, predicted CUD symptom counts in young adulthood even after controlling for demographics and the frequency of adolescent cannabis use. The effect sizes for these two variables were small, however. These findings are similar to those reported by Tucker et al. (2006), who found that solitary cannabis use in eighth grade predicted the endorsement of a single dichotomous item assessing drug problems at age 23 after controlling for eighth grade cannabis use. In our most strict test of predictive associations, the solitary use variables did not remain significant in the prediction of age 25 CUD symptoms after additionally controlling



for adolescent CUD symptoms. We conclude that evidence for a predictive association is mixed and that more research is needed to address this issue.

In contrast to solitary alcohol use in adolescence, which predicted young adult alcohol problems even after controlling for adolescent alcohol use and problems (see Creswell et al., 2014), adolescent solitary cannabis use appears to be a less robust predictor for later cannabis problems. Interestingly, the prevalence rates of solitary cannabis use by adolescents in the current sample and in a large, nationally representative sample of high school seniors (McCabe et al., 2014) indicates that solitary cannabis use is at least twice as common as solitary alcohol use (Creswell et al., 2014). The greater prevalence of adolescent solitary cannabis use suggests that this behavior may be more normative than adolescent solitary alcohol use, and less indicative of vulnerability for substance use problems in young adulthood.

This study has limitations that warrant comment. First, the sample was largely drawn from clinical sources, which limits the generalizability of our findings. It will be important to replicate our findings in large, longitudinal community studies. Second, there is possible bias due to attrition over follow-up, since those who were lost to follow-up differed on demographic variables and recruitment source (but not on CUD severity) compared to those who completed the age 25 assessment. It is unclear how attrition might have influenced the findings. Third, the majority of young adults who had at least one CUD symptom (97%) also met criteria for at least one CUD symptom at some point during adolescence (ages 12–18), so there is the possibility that our prospective findings show a persistence of problems that do not involve a causal role of adolescent solitary use. Fourth, this study did not examine mechanisms that explain how solitary cannabis use may relate to cannabis problems cross-sectionally or longitudinally. Prior studies on adolescent solitary alcohol use have tended to support a self-medication framework, in which adolescents engage in solitary drinking to cope with or relieve negative affect (e.g., Creswell et al., 2014, 2015; Tomlinson and Brown, 2012). There is some evidence that adolescent solitary cannabis users also hold more negative reinforcement expectancies (e.g., beliefs that cannabis use will help them to relax, get away from their problems) than social-only users (Tucker et al., 2006, 2014), and future research should focus on identifying reasons for the emergence of solitary cannabis use among adolescents. Such research will have important clinical implications insofar as it reveals potential targets for intervention in a subset of adolescents who may be vulnerable to the development of cannabis problems in young adulthood.

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### Authors' contribution

K.G.C. and C.S.M. had the initial idea. K.G.C. conducted background literature searches, ran the statistical analyses, and wrote the first draft of the manuscript. D.B.C., C.S.M., and T.C. were involved in the original study protocol and data collection, and they provided critical feedback on the manuscript. All authors reviewed and approved the final version of the manuscript.

### Conflict of interest

Nothing declared.

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