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Frequent teenage cannabis use: Prevalence across adolescence and associations with young adult psychopathology and functional well-being in an urban cohort

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ABSTRACT

Background: Amidst cannabis legalization efforts and laws, we do not fully understand how the youngest frequent cannabis users fare during young adulthood. This study aims to 1) examine the prevalence of cannabis use during adolescence, and 2) investigate links of frequent (i.e., weekly or daily) teenage cannabis use with psychopathology and functional well-being at age 20—compared to no or occasional use.

Methods: Data came from a prospective-longitudinal cohort study (assessments from 2004 to 2018, from ages 7–20) in an urban setting (N = 1482). Substance use was assessed with self-reports between ages 13 and 20. At age 20, participants reported on psychopathology (psychotic symptoms, problematic substance use, aggression, and internalizing symptoms) and functional well-being (delinquency, financial difficulties, social exclusion, general well-being, and not being in education, employment, or training). Covariates were based on self-, parent-, teacher-, and behavioral measures.

Findings: Almost one in five adolescents had used cannabis frequently between ages 13 and 17 (26.6% of males, 9.8% of females). Adjusting nearly 20 potential confounders, frequent teenage cannabis use was associated with age 20 problematic substance use and poorer functional well-being compared to the no cannabis use and the occasional use groups. Frequent teenage cannabis use was more consistently associated with age 20 functional outcomes compared to frequent teenage nicotine or alcohol use.

Conclusions: Frequent teenage cannabis use was common and associated with problematic substance use, more delinquency, and poorer functional well-being at age 20. Accordingly, frequent teenage cannabis users could experience increased difficulties in mastering the transitions of young adulthood.

1. Introduction

Legal and illegal substance use is one of the biggest challenges facing young people in the Western world today. Early substance use in particular is associated with a range of negative outcomes, with high costs for individuals and societies (Degenhardt et al., 2016; Erskine et al., 2015; Vonmoos et al., 2013). In addition to nicotine and alcohol, cannabis is one of the most commonly used drugs (Volkow et al., 2014). Cannabis use during later adolescence and young adulthood, especially frequent use, has been linked with later illicit and problematic drug use (Blanco et al., 2016; Boden et al., 2020; Volkow et al., 2014); certain psychiatric disorders such as psychosis (Arseneault et al., 2002; Bourque et al., 2018; Fergusson et al., 2005b; Volkow et al., 2014); poorer functional outcomes, including delinquency, financial and social

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problems into midlife (Boden et al., 2020; Cerda et al., 2016; Degenhardt et al., 2013; Fergusson et al., 2002; Green et al., 2017; Horwood et al., 2012; Horwood et al., 2010; Silins et al., 2014, 2015; Taylor et al., 2017), and reduced intellectual ability (Meier et al., 2012) and educational attainment (Horwood et al., 2010; Silins et al., 2014, 2015).

Evidence for associations between adolescent/young adult cannabis use and other psychiatric outcomes (e.g., depression, anxiety) is less consistent (Agrawal et al., 2017; Boden et al., 2020; Borges et al., 2016; Degenhardt et al., 2003; Lev-Ran et al., 2014; Moore et al., 2007; Silins et al., 2014; Smolkina et al., 2017). For example, in a meta-analysis of prospective-longitudinal analyses, zero of three studies found an associations of cannabis use before age 18 with anxiety; three of seven studies, and also the overall meta-analysis, found a significant association with depression (Gobbi et al., 2019). Knowledge about the later well-being of the earliest *frequent* cannabis users (i.e., younger than 18 years old) is also limited.

Considering the brain's remarkable malleability during the teenage years—including in response to exposures to psychoactive drugs (Dahl et al., 2018; Fuhrmann et al., 2015; Rubino & Parolaro, 2008; Schneider, 2008; Volkow et al., 2014)—frequent use during these years could be particularly detrimental. A number of cohort studies, including the Dunedin and E-Risk studies (Cerda et al., 2016; Meier et al., 2012, 2018), have assessed problematic and frequent cannabis use from age 18. Others have assessed frequent use at earlier ages (e.g., age 15) but have still missed the earliest teenage years (Boden et al., 2020). Yet others found prevalence rates of early frequent cannabis use to be quite low, making evaluations of links with later outcomes difficult (Copeland et al., 2017). This leaves a gap in knowledge regarding the prevalence and long-term correlates of frequent teenage cannabis use (FTCU), especially in Europe, where rates of teenage substance use tend to be high (Andersson et al., 2009).

Previous cohort studies of later correlates of FTCU have several additional limitations. First, they often do not adjust for other forms of frequent teenage substance use and tend to include limited numbers of covariates. Accordingly, potential confounders of FTCU-outcomes associations are not always adequately taken into account (VanderWeele, 2019). For example, child characteristics such as sensation-seeking and low self-control could explain associations of FTCU with later psychopathology and functioning, but are often not adjusted in previous work. Notably, when several Australasian studies adjusted for large numbers of covariates (e.g., sociodemographics, family functioning, child abuse, childhood characteristics, adolescent behavior), most associations between FTCU and psychopathology and poorer functional well-being in young adulthood remained significant (e.g., Boden et al., 2020; Silins et al., 2014), but these analyses have not been replicated with European samples.

Second, links between FTCU and later externalizing-spectrum outcomes (e.g., aggression, delinquency) are under-examined (e.g., Volkow et al., 2014), perhaps because of cannabis's reputation as a "peaceful" drug (Sandberg, 2012). Some shorter-term studies have reported that conduct problems predicted subsequent cannabis use, but not vice versa (Defoe et al., 2019). Other, longer-term studies reported associations between chronic (frequent) cannabis use and later arrests/convictions (Boden et al., 2020; Green et al., 2010; Pedersen & Skardhamar, 2010; Schoeler et al., 2016), but were not informative about the types of delinquent behaviors (e.g., minor vs. severe). Associations of FTCU with externalizing behaviors deserve additional attention.

We use a prospective-longitudinal cohort study from urban Switzerland to (1) document the prevalence of cannabis use from ages 13–20, and (2) examine links between FTCU from ages 13–17 with a broad range of age 20 indicators of psychopathology (psychosis, problematic substance use, aggression, and internalizing problems) and poor functional well-being (i.e., delinquency, financial difficulties, perceived social exclusion, poor general well-being, and non-participation in education, employment or training). We are particularly interested in *frequent* cannabis use, because frequent exposure to THC may have more potent effects on teenagers' brains and behaviors than rare exposure (Battistella et al., 2014). This could subsequently increase difficulties in mastering the transitions of young adulthood. In addition to direct effects on structural and functional architecture of the brain, frequent early cannabis use could be associated with a preoccupation with drug use over other responsibilities, poor academic attainment (e.g., due to truancy), deviant peer affiliations, involvement in the illicit drug market, and additional outcomes that could impede successful transitioning to young adulthood.

Cannabis use is currently illegal in Switzerland, but possession of small amounts is not punished in some parts of the country; open cannabis use is often tolerated by law enforcement agents (Sznitman, 2009). Where penalties are enforced, they are mild. Legalization debates and trials are underway (Zobel, 2017; Zobel & Maier, 2018; Zobel & Marthaler, 2016), with some proposing 16 as the age of legalization. Accordingly, cannabis use is perceived as relatively safe and normal by Swiss youth (Sznitman, 2009). Large cross-sectional surveys place young people in Switzerland at/above the European average in terms of cannabis use (Andersson et al., 2009). We leverage these high rates of early use to gain deeper insights into how FTCU unfolds, and how it is associated with young adult psychopathology and functional well-being.

2. Material and methods

2.1. Sample and procedures

Data came from the longitudinal *Zurich Project on Social Development from Childhood to Adulthood* [*z-proso* (Ribeaud & Eisner, 2010)]. Participants were selected using a cluster-stratified randomized sampling approach. In 2004, a sample of 1675 children from 56 primary schools was randomly selected from 90 public schools in Zurich, Switzerland's largest city. Stratification was performed by taking into account school sizes and socio-economic background of school districts. The sample was generally representative of first-graders attending public schools in the city of Zurich. Participants were last assessed in 2018 (at age 20).

Frequency of substance use was assessed from age 13 onward [N = 1362; N = 1443; N = 1305; N = 1180 at ages 13 (grade 7), 15 (grade 9), 17 (grade 11), and 20, respectively]. For descriptive analyses, we used all available data at each age. For predicting young adult outcomes, we used data from participants with at least one assessment between ages 13 and 17 (N = 1482), combined with multiple imputation methods. Of N = 1482 participants, 51.8% were male. The majority were born in Switzerland (90.5%). Consistent with Switzerland's immigration policies and Zurich's diverse population, parents of participants had been born in >80 countries. Parental educational background was diverse; 26.2% of families had > 1 parent with a university degree. The mean household International Socio-Economic Index of Occupational Status (Ganzeboom et al., 1992) score was 45.74 (SD=19.24). This is an internationally comparable index of socio-economic status based on occupation-specific income and required educational level [range = 16 (e.g., unskilled worker) to 90 (e.g., judge)].

The study is consistent with national and international ethics standards and was approved by the responsible ethics committee. Adolescents provided written informed consent for their study participation; parents of those 15 and younger could opt their child out of the study. Data were collected from groups of 5–25 participants in classroom-based settings with paper-and-pencil questionnaires until age 17 and in a computer laboratory setting with computer-administered surveys at age 20. Survey completion typically took ~90 min. Adolescents received a cash incentive for their participation (from ~$30 at age 13 to ~$75 at age 20). Parents participated to child age 11, and received $25 for their participation. Teachers participated to child age 17.

2.2. Measures

Past-year cannabis use was self-reported at ages 13, 15, 17, and 20.

Table 1
Measurement of all covariates included in the final adjusted analyses. (Note: Scales without references were created by the study team).

Risk Factor	Definition/Assessment
Other teenage substance use (ages 13–17)	
Frequent nicotine use	• At ages 13, 15, and 17, youth rated their frequency of nicotine use during the past year, with: 1 = *never*, 2 = *once*, 3 = *2–5 times*, 4 = *6–12 times (monthly use)*, 5 = *13–52 times (weekly use)*, and 6 = *53–365 times (daily use)*. A dichotomous *frequent nicotine use* variable was coded 1 when adolescents endorsed having used nicotine weekly or daily (categories 5 or 6) during at least one of the 13, 15, or 17-year assessments. A dichotomous *occasional nicotine use* variable was coded when adolescents endorsed categories 2, 3, or 4 (i.e., one-time to monthly use) at least once between ages 13–17 and did not endorse weekly or daily use.
Frequent alcohol use	• At ages 13, 15, and 17, youth rated their frequency of alcohol use in the past year (i.e., beer, wine, liquor, or alcopops), using the same frequency scale as for nicotine use. Dichotomous frequent alcohol use and occasional alcohol use variables were coded using the same coding scheme as described for cannabis and nicotine use.
Demographics/Family risk	
Sex	• 1 = *male*.
Parental income (age 7)	• Parents reported their household income in the first survey wave on a 10-point scale ranging from 1 = *0–1999 CHF/month* to 10 ≥ *15,000 CHF/month* (M = 5.98, SD = 1.96).
Low parental education	• Both parents held less than a university degree.
Migration background	• Both parents were born abroad (versus at least one parent born in Switzerland).
Parental separation (<age 11)	• Reported by adolescents (1 = *parental separation*).
Harsh parenting (age 11)	• Reported by adolescents using five items from the Alabama Parenting Questionnaire (Shelton et al., 1996; Topçuoğlu et al., 2014), which assessed frequency of harsh parenting (e.g., corporal punishment, yelling) on a four-point scale (1 = *never* to 4 = *very often*). Items were averaged (Cronbach's α = 0.66). Subsequently, those with scores in the top 25% on this scale were assigned a code of 1 for a binary harsh parenting variable.
Own and others' drug use	
Maternal drug use during pregnancy	• Reported on binary items by mothers in the first survey wave. Specifically, mothers reported whether they had consumed cigarettes or alcohol or used other drugs (e.g., cannabis) during their pregnancy with the participating child. A binary variable coded any drug use during pregnancy.
Substance use by peers (age 11)	• Participants were asked to name two best friends and to indicate, on binary items, whether these had consumed cigarettes, alcohol, or other drugs in the past year. A binary variable was created indicating whether at least one friend had used substances.
Own substance use (age 11)	• Self-reported on three items which asked whether the adolescents had used alcohol, nicotine, or cannabis. A binary variable was created indicating *any* versus *no substance use*.
Child risk factors	
Low self-control (age 11)	• Self-reported on 10-items (e.g., "I often act on the spur of the moment without stopping to think"), which were rated on a scale ranging from 1 = *fully untrue* to 4 = *fully true* (Grasmick et al., 1993). Items were averaged (Cronbach's α = 0.75).
Sensation-seeking (age 7)	• Behavioral measure, administered by trained interviewers. Based on an adapted 9-item version of the Travel Game (Alsaker & Gutzwiller-Helfenfinfer, 2010; Murray et al., 2017). A sum score was used (Omega reliability =0.80,Murray et al., 2020). Assessed at age 7 only.
Low academic achievement (age 11)	• Teacher-rated in fourth grade. Up to three teachers rated the participant's academic achievement in math and language compared to the other students in the class (1 = *much worse* to 5 = *much better*). The mean of the teacher ratings for each student was taken. A mean of math and language achievement was created to represent overall achievement. The variable was then recoded, with high values representing low academic achievement.
Outcomes at previous age	
Aggression (age 11)	• Self-reported on 15 items from the physical aggression, proactive aggression, indirect aggression, reactive aggression, and oppositional aggression subscales of the Social Behavior Questionnaire (Tremblay et al., 1991), which were averaged (Cronbach's α = 0.82).
Internalizing symptoms (age 11)	• Self-reported on eight items of the Social Behavior Questionnaire (Tremblay et al., 1991), which were averaged (Cronbach's α = 0.79).
Delinquency (age 11)	• Assessed in the same way as at age 20, with a list of nine delinquent behaviors, which were summed (Eisner et al., 2000; Ribeaud & Eisner, 2009; Wetzels et al., 2001, adapted and expanded).
Perceived social exclusion (age 13)	• Assessed with five items (e.g., "I get excluded";Bude & Lantermann, 2006), which were averaged (Cronbach's α = 0.86).

Frequency of cannabis use during the past year was assessed with: 1 = *never*, 2 = *once*, 3 = *2–5 times*, 4 = *6–12 times (monthly use)*, 5 = *13–52 times (weekly use)*, and 6 = *53–365 times (daily use)*. The words "monthly," "weekly", and "daily" were displayed on the questionnaires. For descriptive analyses, we coded 1) a dichotomous variable indicating whether adolescents had used any cannabis during the past year (past-year prevalence), and 2) the complete frequency scale to assess past-year frequency of cannabis use. In regression analyses predicting psychopathology and functional well-being at age 20, a dichotomous FTCU variable was coded 1 when adolescents endorsed weekly or daily cannabis use (categories 5 or 6) during any of the 13, 15, or 17-year assessments. A dichotomous "occasional use" variable was coded 1 when adolescents endorsed categories 2, 3, or 4 (i.e., one-time to monthly use) during any of the 13, 15, or 17-year assessments, but did not endorse weekly or daily use. All other adolescents were coded into a "no cannabis use" group.

2.2.1. Outcome measures: Self-reported psychopathology and substance use outcomes, Age 20

Psychosis symptoms were assessed using six items adapted from the Community Assessment of Psychic Experiences (Mark & Toulopoulou, 2016). Participants were asked how often they had experienced symptoms during the past month (e.g., heard voices that no one else could hear), with 1 = *never* to 5 = *very often*. Items were averaged (Cronbach's α = 0.69). *Problematic substance use* was assessed with a 17-item checklist of substances (including alcohol, cannabis, several opioids, stimulants, and hallucinogens), using the same frequency scale as for cannabis. Participants were assigned a score of 1 on a binary problematic substance variable when they had used *illicit substances* at least once during the past year, or alcohol daily or cannabis weekly or daily. An alternative version of this variable, used in follow-up analyses only, coded illicit substance use only, without including cannabis use. *Physical aggression* was assessed with three items from the Social Behavior Questionnaire (Murray et al., 2019; Tremblay et al., 1991). For example, participants were asked to indicate how often during the past year they had physically attacked someone (1 = *never,* 2 = *rarely* to 5 = *very often*). The continuous physical aggression variable was highly skewed. Therefore, if participants reported physical aggression on any of the three physical aggression items, they were assigned a 1 on a dichotomous physical aggression variable. *Internalizing symptoms* were assessed with 13 items from the Social Behavior Questionnaire (Tremblay et al., 1991) addressing past-month depressive and anxiety symptoms, and two items assessing suicidal ideation and self-injury on a scale from 1 = *never* to 5 = *very often*. Items were averaged (Cronbach's α = 0.92).

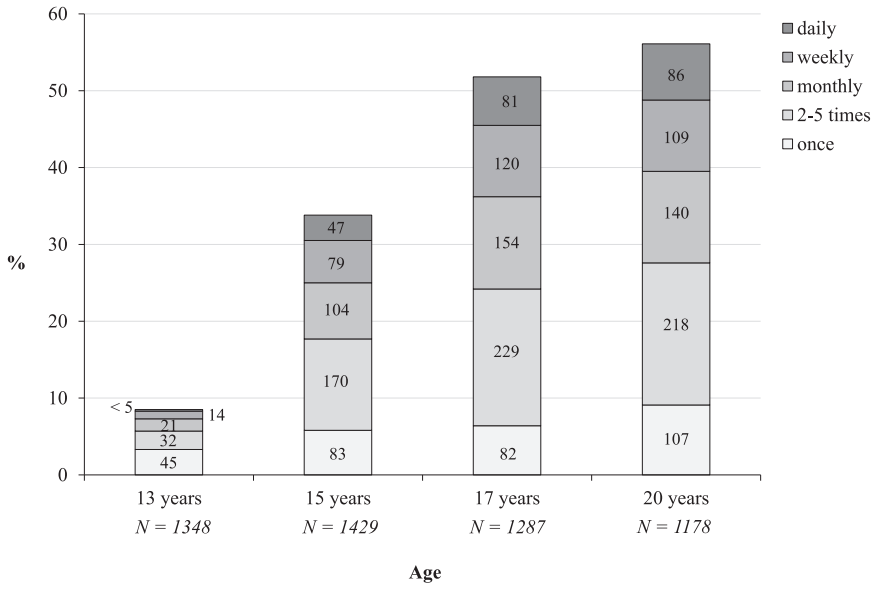

Fig. 1. Past-year prevalence and frequency of cannabis use from ages 13–20.

Table 2
Descriptive statistics of all variables used in regression models predicting age 20 psychopathology and functional well-being outcomes, based on N = 1153 participants at age 20 with data on FTCU.

Variable and Range (in Parentheses)	No Use 13–17 43.2%, n = 498		Occasional Use 13–17 38.6%, n = 445		FTCU 13–17 18.2%, n = 210	
	%	M (SD)	%	M (SD)	%	M (SD)
Outcomes at Age 20 *(Range)*						
Psychopathology and Substance Use						
Psychosis symptoms *(1–5)*		1.44 (0.54)		1.45 (0.48)		1.55 (0.53)
Problematic substance use (1 = yes)	15.8		50.9		85.8	
Physical aggression *(1 = any)*	18.8		21.9		37.5	
Internalizing symptoms *(1–5)*		2.17 (0.78)		2.14 (0.70)		2.16 (0.72)
Functional Well-Being						
Delinquency *(1–24)*		1.67 (1.58)		2.63 (2.01)		3.95 (2.84)
Debt (1 = yes)	17.1		21.6		32.6	
General well-being *(1–4)*		3.20 (0.59)		3.27 (0.56)		3.12 (0.59)
Perceived social exclusion *(1–4)*		1.50 (0.61)		1.48 (0.55)		1.62 (0.59)
Not in education, employment, or training (1 = yes)	1.9		2.8		6.5	
Other Teenage Substance Use (Ages 13–17)						
Frequent teenage nicotine use (1 = yes)	16.5		44.3		73.2	
Occasional teenage nicotine use (1 = yes)	40.7		49.8		26.3	
Frequent teenage alcohol use (1 = yes)	5.3		35.4		58.9	
Occasional teenage alcohol use (1 = yes)	64.6		61.6		40.7	
Childhood Covariates *(Range)*						
Demographics/Family Risk						
Sex (1 = male)	41.8		48.1		72.9	
Parental income at intake, age 7 *(1–10)*		5.95 (1.81)		6.15 (2.01)		6.10 (1.88)
Low parental education (1 = no university degree)	77.4		68.9		72.2	
Migration background (1 = both parents born abroad)	59.9		41.1		36.5	
Parental separation before age 11 (1 = yes)	17.8		27.1		32.9	
Harsh parenting at age 11 (1 = in top quartile)	18.0		20.3		27.0	
Own and Others' Drug Use						
Maternal drug use during pregnancy (1 = yes)	31.6		37.8		51.1	
Substance use by peers at age 11 (1 = yes)	2.8		9.1		17.5	
Substance use at age 11 (1 = yes)	3.9		8.5		15.6	
Child Risk Factors						
Low self-control at age 11 *(1–4)*		1.81 (0.43)		2.00 (0.44)		2.10 (0.49)
Sensation-seeking at age 7 *(1–4)*		0.51 (0.25)		0.58 (0.24)		0.67 (0.23)
Low academic achievement at age 11 *(1–5)*		2.85 (1.15)		2.52 (1.07)		2.57 (1.07)
Outcomes At Previous Age						
Aggression at age 11 *(1–5)*		1.32 (0.44)		1.40 (0.55)		1.73 (0.79)
Internalizing symptoms at age 11 *(1–5)*		2.01 (0.65)		2.10 (0.65)		2.05 (0.66)
Delinquency at age 11 *(0–9)*		0.63 (0.85)		1.05 (1.17)		1.56 (1.56)
Perceived social exclusion at age 13 *(1–4)*		1.47 (0.52)		1.50 (0.52)		1.53 (0.55)

FTCU = frequent teenage cannabis use (i.e., weekly or daily) Note: The sample size for the different predictors examined here varied (N = 873–1153); as described in the analytic strategy section, missing values were imputed in subsequent regression analyses.

Table 3a
Unadjusted associations of teenage cannabis use and young adult psychopathology and functional outcomes. Rows represent outcomes, columns represent predictor variables (i.e., the frequency of cannabis use).

Outcomes	Frequent vs no use			Frequent vs occasional use			Occasional vs no use		
	β[a]/OR[b]	CI[c]	*p*	β[a]/OR[b]	CI[c]	*p*	β[a]/OR[b]	CI[c]	*p*
Psychopathology Outcomes									
Psychosis symptoms[a]	0.09	0.02—0.16	0.011	0.09	0.02—0.15	0.011	0.00	-0.06—0.07	0.950
Problematic substance use[b]	**22.89**	15.23—34.41	<0.001	**5.03**	3.36—7.53	<0.001	**4.55**	3.32—6.23	<0.001
Physical aggression[b]	**2.73**	1.91—3.89	<0.001	**2.28**	1.59—3.25	<0.001	1.20	0.88—1.64	0.259
Internalizing symptoms[a]	0.01	-0.05—0.07	0.764	0.03	-0.03—0.09	0.371	-0.02	-0.09—0.04	0.474
Functional outcomes									
Delinquency[a]	**0.38**	0.32—0.44	<0.001	**0.22**	0.14—0.29	<0.001	**0.20**	0.15—0.25	<0.001
Debt[b]	**2.04**	1.39—2.98	<0.001	**1.79**	1.25—2.57	0.001	1.14	0.81—1.59	0.453
General well-being[a]	-0.06	-0.13— −0.001	0.046	**-0.11**	-0.18— −0.04	0.001	0.06	-0.01— −0.12	0.095
Perceived social exclusion[a]	**0.09**	0.03—0.16	0.005	**0.10**	0.04—0.16	0.002	-0.01	-0.08—0.06	0.769
Not in education, employment[b]	**5.12**	2.22—11.83	<0.001	**2.77**	1.41—5.47	0.003	1.85	0.75—4.55	0.170

Note. p-value refers to unstandardized logit coefficient in the case of logistic regressions. Bolded values are significant at $p < .0055$.
[a] standardized linear regression coefficient β for linear regressions
[b] odds ratios for logistic regressions
[c] 95% confidence interval

Table 3b
Adjusted associations of teenage cannabis use and young adult psychopathology and functional outcomes. Rows represent outcomes, columns represent predictor variables (i.e., the frequency of cannabis use).

Outcomes	Frequent vs no use			Frequent vs occasional use			Occasional vs no use		
	β[a]/OR[b]	CI[c]	*p*	β[a]/OR[b]	CI[c]	*p*	β[a]/OR[b]	CI[c]	*p*
Psychopathology Outcomes									
Psychosis symptoms[a]	0.08	0.00—0.16	0.040	0.08	0.02—0.15	0.012	0.00	-0.08—0.08	0.996
Problematic substance use[b]	**10.13**	5.96—17.22	<0.001	**3.87**	2.47—6.07	<0.001	**2.61**	1.81—3.79	<0.001
Physical aggression[b]	1.47	0.88—2.48	0.145	1.41	0.92—2.18	0.116	1.04	0.70—1.55	0.844
Internalizing symptoms[a]	0.05	-0.02—0.12	0.192	0.07	0.01—0.13	0.019	-0.03	-0.10—0.04	0.417
Functional outcomes									
Delinquency[a]	**0.20**	0.12—0.27	<0.001	**0.14**	0.07—0.22	<0.001	0.07	0.00—0.13	0.038
Debt[b]	1.74	1.03—2.95	0.039	**1.78**	1.17—2.71	0.006	0.98	0.64—1.48	0.910
General well-being[a]	**-0.10**	-0.18— −0.03	0.008	**-0.13**	-0.20— −0.06	<0.001	0.03	-0.04—0.10	0.382
Perceived social exclusion[a]	0.09	0.01—0.16	0.026	**0.10**	0.04—0.16	0.001	-0.02	-0.10—0.06	0.614
Not in education, employment[b]	**6.71**	2.00—23.06	0.002	**3.40**	1.42—8.12	0.004	1.98	0.61—6.44	0.259

Note. p-value refers to unstandardized logit coefficient in the case of logistic regressions. Multivariable models adjusted for the outcome at a previous time point when possible (typically at age 11), and also for all covariates shown in Table 1. Bolded values are significant at $p < .0055$.
[a] standardized linear regression coefficient *β* for linear regressions
[b] odds ratios for logistic regressions
[c] 95% confidence interval

2.2.2. Outcome measures: Self-reported delinquency and functional well-being, age 20

Delinquency in the past year was assessed with a 24-item binary checklist of behaviors (see Table S2 in **Supplement** for list), with 1 =*present*. Both minor (e.g., skipping work, producing illegal graffiti) and severe delinquent acts (e.g., vehicle theft) were assessed. All items were summed, with higher scores reflecting more delinquent behaviors. For follow-up analyses, minor and severe delinquent behaviors were summed into separate variables. *Debt* was assessed using four dichotomous items asking whether participants owed money to family members, partners, friends, or a bank. A binary variable was created indicating *any* versus *no debt*. *General well-being* was assessed using four items asking participants how they felt about life at the moment (e.g., "I am very happy and content") on a scale from 1 = *not at all true* to 4 = *very much true*. Items were averaged (α = 0.81).

Perceived social exclusion was assessed using six items asking about participants' feelings of not belonging with other people or society [e.g., "I feel like I don't really belong to society" (Bude & Lantermann, 2006)], on a scale from 1 = *not at all true* to 4 = *very much true*. Items were averaged (α = 0.88). *Not in education, employment, or training* (NEET) was coded 1 when participants held a compulsory school degree or had completed a preparatory vocational bridge year, but were currently unemployed (Bynner & Parsons, 2002). Everyone with more education/training was coded 0. Compulsory schooling in Switzerland ends after 9th grade and school drop-out is exceedingly rare.

2.2.3. Control variables

Detailed descriptions of all covariates and their psychometric properties are shown in Table 1. In addition to frequent nicotine and alcohol use, we included covariates that are plausible confounders of FTCU-outcomes associations, including some that have rarely been tested in prior research (e.g., childhood sensation-seeking, self-control). Whenever possible, child-level covariates were coded *prior* to frequent substance use (e.g., at age 11), otherwise at age 13. When possible, we included covariates that indexed the outcomes at previous ages (e.g., previous internalizing symptoms at age 11). This allowed us to test whether FTCU predicts *decreases* in well-being and *increases* in psychopathology over time. Covariates were measured using parent-, teacher-, and child self-reports, and also a behavioral measure (i.e., for sensation-seeking). This large list of covariates was included to rule out confounding in FTCU-outcomes associations (VanderWeele, 2019) and to strengthen conclusions about the direction of effects of associations between FTCU and later outcomes. Hypotheses regarding covariates-outcomes associations were not tested.

2.3. Analytic strategy

We computed the 12-month prevalence and frequency of cannabis use at each age. We tested associations of FTCU with age 20 psychopathology and well-being using multiple regression analyses in M*plus* (Muthen & Muthen, 2012), adjusting for all control variables. One multivariable analysis was run for each of the 9 outcome variables,

respectively. To account for multiple testing, we interpreted FTCU-outcomes associations only when they were significant at $p < .05/9$ ($p < .0055$). We specified linear models for continuous outcomes, and binary logistic regressions for dichotomous outcomes. We used the Maximum Likelihood Robust estimator, which is robust to non-normal data. To address any potential bias due to attrition, we used multiple imputation to handle missing data in our multivariable analyses (Enders, 2017; Schafer & Graham, 2002). The imputation model included all variables used in our main models (Bayesian estimation, as implemented in M*plus*; missing values on predictors and outcomes were imputed from an unrestricted model). Twenty imputed data sets were generated. All participants who provided data on cannabis use at least once between ages 13 and 17 were included (N = 1482). Parameter estimates were averaged across the imputed data sets; standard errors were pooled following Rubin's rules (Rubin, 1987).

3.0. Results

3.1. Cannabis use from ages 13–20

Fig. 1 shows past-year prevalence and frequency of cannabis use at ages 13, 15, 17, and 20. At age 13, almost 10% of participants had used cannabis in the past year, and one in three had used cannabis in the past year at age 15. Occasional use was relatively common at 25.0% and 36.2% at ages 15 and 17, respectively. Frequent use was near 10% at age 15 and > 15% at age 17 years. Indeed, by age 17, 18.2% (N = 210) of participants had reported weekly or daily cannabis use during at least one assessment; an additional 38.6% (N = 445) had reported occasional cannabis use. Fig. S1 and Table S1 in the **Supplement** show sex differences in cannabis use. Cannabis use was more prevalent in males than in females at each age. By age 17, 26.6% (N = 153) of males and 9.8% (N = 57) of females had used cannabis frequently at some point.

3.2. Predicting age 20 psychopathology and functional well-being with frequent cannabis use between ages 13 and 17

Table 2 shows descriptive statistics of all study variables for the no use, occasional use, and frequent teenage cannabis use groups; Table 3a shows unadjusted odds ratios for the association of these variables with all outcomes. In terms of psychopathology, FTCU was associated with higher likelihood of problematic substance use and physical aggression at $p < .0055$ compared to the no use and the occasional use groups. In terms of functional well-being, FTCU was associated with less well-being in terms of almost all outcomes.

Table 3b shows results from adjusted regression analyses. Coefficients of covariates are not shown in this table, because our research question focused on exposure-outcome associations specifically (Westreich & Greenland, 2013). Some associations from the unadjusted models were attenuated in size. Compared to occasional cannabis use, FTCU was associated with a higher likelihood of age 20 substance use problems and poorer well-being in all functional outcomes. Compared to no teenage cannabis use, FTCU was associated with more problematic substance use, delinquency, poorer general well-being, and NEET.

Associations of FTCU with age 20 problematic substance use were particularly strong: Frequent teenage cannabis users were 10 times more likely to be problematic substance users at age 20 compared to cannabis-abstinent youth after adjusting for all covariates. This association attenuated only slightly when the alternative young adult problematic substance use variable—coding illicit drug use only, without including cannabis use—was used. Among the functional outcomes, the association of FTCU use with later delinquency is particularly noteworthy; this association remained of similar size when deleting physical assault from the delinquency scale to avoid overlap with the physical aggression scale. FTCU also had a large association with NEET at age 20, and a small but significant association with poorer well-being.

3.3. Follow-up analyses

We disaggregated minor and severe delinquency and found that FTCU was associated with both types of delinquency (**Table S2** in **Supplement**). Furthermore, FTCU had more consistent associations with age 20 outcomes compared to frequent teenage nicotine and alcohol (**Table S3** in **Supplement**).

4. Discussion

Amidst cannabis legalization efforts and laws, longer-term, larger-scale, representative, multi-informant cohort studies that combine assessments of early cannabis use and key childhood covariates with broad assessments of young adult psychopathology and functional well-being *in one study* are still rare, especially in Europe. FTCU was common in our sample, especially among males, with almost 1 in 5 participants reporting FTCU by age 17. Adjusting for nearly 20 childhood covariates, FTCU was associated with young adult problematic substance use, and all functional outcomes compared to the occasional use group, and with three of the five functional outcomes and also problematic substance use compared to the no use group.

Associations were strongest (Funder & Ozer, 2019) with subsequent problematic substance use. This is consistent with previous work and suggests that cannabis is a gateway into later problematic substance use (Fergusson et al., 2006). The associations with age 20 functional outcomes—which spanned a considerable range of life domains—indicate that FTCU is a risk marker for future disengagement from society. At the population level, these findings suggest that FTCU could have considerable long-term costs for society. For example, in addition to not successfully completing the transitions of young adulthood along with their peers, individuals with FTCU may be at increased risk for criminal justice involvement, welfare dependence, and health care spending in the long run. These findings are noteworthy considering that some are proposing 16 as the age of cannabis legalization in Switzerland.

Associations with the remaining age 20 indicators (i.e., poor general well-being, perceived social exclusion, debt) were smaller in size. Furthermore, the association with psychosis symptoms was small, and not significant at $p < .0055$). The psychosis literature suggests that cannabis likely increases risk in a small subset of the population with pre-existing psychosis vulnerabilities (Arseneault et al., 2002; Auther et al., 2012; Bourque et al., 2018; Caspi et al., 2005; Griffith-Lendering et al., 2013; Henquet et al., 2005; Moore et al., 2007). Overall, small effect sizes in our study must also be interpreted in light of our inclusion of almost 20 covariates, including nicotine and alcohol use, which were sometimes neglected in previous research (Funder & Ozer, 2019; VanderWeele, 2019). Notably, FTCU was a stronger and more consistent correlate of young adult psychopathology and functional well-being than frequent nicotine or alcohol use (which are legal at age 16 in Switzerland).

Additional findings are noteworthy. First, although associations between cannabis and delinquency tend to be under-examined, FTCU predicted both minor and severe delinquency at age 20, adjusting for age 11 delinquency. Thus, FTCU predicted overall *increases* in delinquency over time. Increased impulsivity and impaired decision-making caused by cannabis (Crane et al., 2013; Crean, Crane, et al., 2011; Crean, Tabert, et al., 2011) could, in part, be driving these findings. Minor acts of delinquency, including skipping work and stealing from parents, could seriously impede successful young adult work and social relationships transitions. Minor acts, such as fare dodging, graffiti, and vandalism, also suggest an antisocial attitude, disengagement from society, and a tendency toward elevated risk-taking in those with FTCU. Note, however, that our findings do not exclude the possibility of some reciprocal associations between mid-adolescent delinquency and later cannabis use (Fergusson et al., 2005a, 2007).

Second, our findings show that by age 17, the majority of adolescents in Zurich use cannabis, indicating that it is the norm at that age in our

population. FTCU was also relatively common at 18.2% overall, and 26.6% among males. These rates are considerably higher than in other contexts, including the United States (e.g., Copeland et al., 2017), which enabled our study to shed light on the young adult correlates of relatively *normative* FTCU. Our findings suggest that in such a setting, FTCU is nevertheless associated with an increased likelihood of symptoms of psychopathology and poorer functional well-being at age 20. Thus, FTCU may be associated with poorer young adult outcomes, regardless of the legal or cultural context in which it occurs, given its effects on the brain and behavior/lifestyle during a vulnerable developmental period (Dahl et al., 2018; Fuhrmann et al., 2015; Miller et al., 2019; Rubino & Parolaro, 2008; Schneider, 2008). Indeed, many frequent users, and most daily users (Copeland et al., 2017), meet criteria for cannabis use disorder, meaning that their lives are altered by addiction.

Occasional teenage cannabis use (compared to no use) was associated with problematic substance use at age 20, but not with any additional outcomes. The lack of associations between occasional cannabis use and other outcomes is consistent with some previous work that suggested a dose-response relationship between teenage cannabis use and later psychopathology and functional well-being (Silins et al., 2014); threshold-based models may also apply. Unfortunately, we cannot forecast which adolescents will transition from occasional to frequent use. Furthermore, at least one other study has reported effects of first-time or rare cannabis use on the brain (Orr et al., 2019).

4.1. Limitations

Our prospective-longitudinal cohort study has many strengths, but also comes with limitations. First, although largely representative of the Zurich area, the study is not representative of the Swiss population in general. The high cannabis use rates in the current study are consistent with rates from cross-sectional samples of adolescents from Zurich, however (Ribeaud, 2015). Second, cannabis use and most adult outcomes were self-reported, resulting in potential biases (most likely, underreporting, e.g., Palamar & Le, 2020; Williams & Nowatzki, 2005). Finally, despite our longitudinal study design and stringent adjustment for pre-existing problem behaviors (e.g., internalizing symptoms at age 11) and many potential confounders, we cannot interpret the associations causally.

4.2. Conclusion

In our sample, FTCU use was relatively common and associated with problematic substance use, and a broad range of functional well-being indicators at age 20. With its relaxed rules and attitudes regarding cannabis use, Switzerland is one of few places in the world where FTCU is high enough for researchers to be able to evaluate associations with later outcomes reliably and with sufficient precision. Our results suggest that FTCU is by no means a harmless phenomenon. The findings should give pause to proponents of cannabis legalization policies that effectively facilitate adolescents' access to cannabis, including policies that aim to legalize cannabis from age 16. Indeed, our findings suggest that we need to increase discussion about how to best protect teenagers, especially males, from frequently using cannabis during a developmental period when their brains and behaviors are highly malleable and vulnerable.

CRediT authorship contribution statement

DR and **ME** planned, implemented, and received funding for the z-proso cohort. **LS** and **BBQ** secured funding for and planned the current analyses. BBQ and LS designed the age 20 drug use questionnaire. **AS** and **LB** conducted the statistical analyses. LS wrote the first draft of the manuscript, with critical input and revisions from **BBQ**, **WEC**, **AS**, **LB**, **DR**, and **ME**. All authors contributed to and have approved the final manuscript.

Author Disclosures

The funding agencies did not influence the analyses, interpretation, and publication of thedata. The authors did not have any conflicts of interest to declare.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personalrelationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.drugalcdep.2021.109063.

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