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Adolescent Cannabis Misuse Scale: Longitudinal Associations with Substance Use, Mental Health, and Social Determinants of Health in Early Adulthood

Background: Some patterns of cannabis use may presage risk for long-term negative effects. We examined associations between a novel adolescent cannabis misuse scale and early-adult life course outcomes.

Methods: We performed a secondary data analysis of a cohort of Los Angeles, CA high school students from grade 9 through age 21. Participants reported baseline individual demographic and family characteristics at grade 9, adolescent cannabis misuse (8-items) and alcohol misuse (12-items) at grade 10, and outcomes at age 21. We used multivariable regression to model the associations of cannabis misuse scale score with problem substance use (defined as any of: 30-day illegal drug use, 30-day use of another's prescription to get high, hazardous drinking) and several secondary outcomes (behavioral, mental health, academic, social determinants of health), adjusting for covariates. Parallel analyses were conducted for alcohol misuse.

Results: The 1,148 participants (86% retention) were 47% male, 90% Latinx, 87% US born, and 40% native English speakers. Approximately 11.4% and 15.9% of participants reported at least one item on the cannabis and alcohol misuse scales, respectively. At age 21, approximately 6.7% of participants reported problem substance use, which was associated with both Cannabis and Alcohol Misuse Scales (OR 1.31, 95%CI[1.16, 1.49] and OR 1.33, 95%CI[1.18, 1.49], respectively). Both scales were similarly associated with outcomes in all four categories.

Conclusions: The Adolescent Cannabis Misuse Scale is a promising tool for identifying early patterns of substance use that predict future negative outcomes and enabling early intervention at a critical period in youth development.

Keywords: Cannabis; Adolescent Health; Substance-Related Disorders/prevention and control; Mental Health; Educational Measurement; Social Determinants of Health; Longitudinal Studies.

Introduction

Cannabis use poses risks to adolescent health and wellbeing (Degenhardt & Hall, 2001; Fergusson & Boden, 2008; Hall, 2009; McCabe et al., 2022; Newton et al., 2013; Volkow et al., 2014), yet not all patterns of use may carry the same harmful impact on long-term health trajectories (Chen et al., 2009; Degenhardt & Hall, 2001; Fergusson & Boden, 2008; Hall & Pacula, 2003). The landscape of cannabis use is changing with broader legalization and a greater diversity of higher potency cannabis products leading to increased access, prevalence of use, and potentially negative consequences (Cerdá et al., 2020; Di Forti et al., 2019; Hasin, 2018; Volkow et al., 2014). As such, we need tools to help identify those adolescents who use cannabis and have the greatest risk of long-term negative outcomes (Asbridge et al., 2014).

The Surgeon General describes misuse broadly as having “related health and social problems and costs” (United States Department of Health and Human Services, Office of the Surgeon General, 2016), yet there is no standard measure of misuse. One approach to characterizing misuse is through the use of a multi-item inventory (Casajuana et al., 2016). In the alcohol misuse literature, Edelen et al. (2009) created the Adolescent Alcohol Misuse Scale, a developmentally-appropriate inventory of items to measure adolescent alcohol misuse starting from grade 7, and examined its predictive validity against the Alcohol Use Disorders Identification Test (AUDIT) at age 21. The scale identifies short-term negative consequences of alcohol use which can serve as proxies for misuse and predict subsequent long-term negative outcomes. While alcohol and cannabis may have different developmental and neurophysiological effects, such a tool for cannabis use could help 1) describe adolescent patterns of use associated with morbidity during the transition to adulthood and 2) identify high risk populations for

directed intervention. A critical first step is to validate the tool against a holistic set of long-term negative outcomes that have relevance to life course health and well-being (Halfon et al., 2022).

Here we conduct a secondary analysis of a longitudinal cohort in which participants completed a multi-item inventory of cannabis use, the Adolescent Cannabis Misuse Scale, at multiple time points from early adolescence to early adulthood. The Adolescent Cannabis Misuse Scale, adapted from Edelen et al.'s Alcohol Misuse Scale, contains seven developmentally appropriate items related to problematic or hazardous cannabis use. Our objective was to provide construct validity of this multifaceted measure of adolescent cannabis misuse by 1) describing how patterns of misuse change over time through adolescence and early adulthood, 2) examining the misuse scale measured in middle adolescence and its association with behavioral, mental health, academic, and other life outcomes during early adulthood, and 3) testing associations between individual scale items and problematic substance use during early adulthood. As preliminary support for the construct validity of the Adolescent Cannabis Misuse Scale, we performed parallel analyses using the Adolescent Alcohol Misuse Scale for comparison.

Materials and Methods

Study design and sample

We analyzed longitudinal data from the Reducing Health Inequalities through Social and Educational Change Follow Up (RISE-UP) study, a natural experiment designed to assess the effects of high-performing high schools on health behaviors among low-income, minority adolescents in Los Angeles. The study has been described previously

(Dudovitz et al., 2018; Wong et al., 2022). In the spring of 2013 and 2014, student participants were randomly sampled from a register of 9th grade admissions lottery applicants to one of five high-performing charter high schools in Los Angeles County, defined as: (1) enrolling predominantly economically disadvantaged students (i.e., qualifying for free or reduced lunch) and (2) academically performing in the top tertile of public schools in Los Angeles County based on 2012 Academic Performance Index derived from standardized test scores. Both lottery “winners” (who were offered admission to these schools) and those “wait-listed” (not offered admission) were sampled. Participants had to reside in Los Angeles County and speak English or Spanish fluently. Of 1509 eligible students, 1270 (84%) enrolled in the study. The institutional review board of the University of California Los Angeles and RAND Corporation have approved this study. Written parental consent and student assent were obtained from all participants.

Data Collection

For these analyses, we utilized five waves of data collected from March 2013 through June 2021. Baseline data were collected from March of grade 8 through November of grade 9 (age 14). Follow-up surveys were administered annually thereafter in the spring: grade 10 (age 16), grade 11 (age 17), age 20, and age 21. All interviews were conducted via a computer assisted survey instrument in the participant’s preferred language with the support of bilingual research assistants and in a private location of the participant’s choice. This computer-assisted self-interview method has been shown to reduce social desirability bias for sensitive topics in adolescence including substance use (Booth-Kewley et al., 2007; Kurth et al., 2004; Perlis et al., 2004). Most interviews were conducted in-person, however, data from the last two waves were collected in-person or

by phone.

Early Adulthood Outcomes

Participants self-reported outcomes for this analysis as part of the age 21 survey.

Outcomes were classified into four categories: behavioral, mental health, academic, and social determinants of health. Behavioral outcomes included problem substance use, cigarette smoking, vaping, hazardous drinking, high risk sex, delinquent behaviors, and physical fighting. Problem substance use was a binary composite measure (any/none) of the following: use of any illegal drugs in the last 30 days (e.g., “opiates, amphetamine, methamphetamine, PCP, or cocaine”), use of another person’s prescription drugs to get high in the last 30 days, and hazardous drinking as defined by an Alcohol Use Disorder Identification Test (AUDIT) score ≥ 8 (Saunders et al., 1993). These outcomes represent three critical categories of substance use: those with legal implications, the fastest growing substance use problem in the USA, and the most prevalent substance use problem in the USA, respectively (Behavioral Health Coordinating Committee & Prescription Drug Abuse Subcommittee, 2013; *Key Substance Use and Mental Health Indicators in the United States: Results from the 2020 National Survey on Drug Use and Health*, 2020). Participants reported frequency of cigarette use in the last 30 days (any/none) and use of a vaping device in the last 30 days (any/none). They also reported on any of the following risky sex behaviors in the last 3 months (any/none): condomless sex, multiple sexual partners, sex while using alcohol or drugs, or ever becoming pregnant. Using the National Longitudinal Study of Adolescent to Adult Health (Add Health) delinquent behaviors index (Haynie & Osgood, 2005), participants reported delinquent behaviors including: painting graffiti, damaging someone else’s property, shoplifting or stealing, running away from home, driving a car without the owner’s

permission, burglary, armed robbery, selling illicit drugs, participation in a gang in the last year, and having ever participated in a gang fight (any/none). Finally, students were asked if they had been in a physical fight in the last 12 months (yes/no).

Mental health outcomes included: languishing-flourishing, depression, anxiety, and post-traumatic stress disorder. Acknowledging that mental health is not simply the absence of mental illness but incorporates positive feelings (emotional well-being) and positive functioning (psychological and social well-being), the languishing-flourishing continuum was assessed using the Mental Health Continuum Short Form (Lamers et al., 2011) in which flourishing was defined as reporting ≥ 1 of 3 hedonic signs and ≥ 6 of 11 eudaimonic signs experienced “every day” or “5-6 times a week” (flourishing/not). Depression was assessed using the Center for Epidemiologic Studies Depression Scale Shortened version (CESD-10) (Andresen et al., 1994; Furukawa et al., 1997; Radloff, 1977) on which a score of 10 or greater has optimal test characteristics for the diagnosis of depression (Andresen et al., 1994; Boey, 1999) (depression present/absent). Anxiety was assessed using the General Anxiety Disorder-7 and dichotomized at ≥ 8 for moderate to severe anxiety (moderate to severe anxiety/none or mild anxiety) (Kroenke et al., 2007; Ruiz et al., 2011; Spitzer et al., 2006). Screening for post-traumatic stress disorder was performed using the Primary Care PTSD Screen for DSM-5 (PC-PTSD-5) with a cutoff of ≥ 4 indicating probable PTSD (Prins et al., 2016) (probable PTSD present/absent).

Academic outcomes included: English and Math proficiency, high school graduation, and 4-year college matriculation. Math and English proficiency were determined by the California Assessment of Student Performance and Progress taken by students in grade 11 (proficient or above/failed to meet standard for grade level). We

obtained high school graduation from school records (graduated/not). We obtained data on college matriculation into a 4-year college from the National Student Clearinghouse, a non-profit organization providing enrolment and degree-verification services to colleges and universities. These data were obtained on 10/30/2019 corresponding to about 1.5-2.5 years after the end of grade 12 (matriculated in a 4-year college/not).

Social determinants of health outcomes included: housing insecurity, food insecurity, transportation insecurity, social isolation, and history of arrest. While these outcomes do not represent the full scope of health determinants created by social and political processes, they are both relatively prevalent and consistently associated with poor adult health (Holt-Lunstad & Steptoe, 2022; Marmot et al., 2012; Murthy, 2020; Parekh et al., 2022; Tolliver et al., 2022). Housing insecurity, food insecurity, transportation insecurity, and social isolation were screened for using the Accountable Health Communities Screening Tool (Centers for Medicare and Medicaid Services et al., 2017). Housing insecurity was defined as not having a “steady place to live” (present/absent). Food insecurity was identified if the participant responded affirmatively to any of the following within the past 12 months: 1) “you were worried that your food would run out before you got money to buy more” or 2) “the food you bought just didn’t last and you didn’t have money to get more” (present/absent). Transportation insecurity was assessed with the single item “In the past 12 months, has lack of reliable transportation kept you from medical appointments, meetings, work or from getting things needed for daily living?” (yes/no). Social isolation was assessed with the item “How often do you feel lonely or isolated from those around you?” (yes/no). Participants self-reported lifetime history of arrest (once or more/never).

Adolescent Substance Misuse Scales

We administered two substance misuse scales to assess high risk substance use behaviors (use of alcohol/cannabis on school property, using by oneself, binge use) and negative consequences (blacking out, missing school, regret, getting into trouble at school, getting into trouble at home, and poor concentration). The Adolescent Alcohol Misuse Scale (Edelen et al., 2009) contains 12 items, each scored with a value of one or zero (endorsed/not) and summed to produce a continuous scale from zero to 12 (higher scores indicate more negative behaviors or consequences). The Adolescent Cannabis Misuse Scale (See Supplement 1) is a seven-item inventory adapted from the Adolescent Alcohol Misuse Scale and scored using the same method. Most items from the alcohol scale were directly adapted for cannabis (e.g., missed school because of using alcohol/cannabis), some were removed due to the different physiologic effects of cannabis or lack of supporting literature (e.g., passing out from alcohol use, binge drinking), and one was added (i.e., trouble concentrating). The Adolescent Alcohol Misuse Scale was administered at baseline, grade 10, and grade 11. The Adolescent Cannabis Misuse Scale ($\alpha = 0.85$) was administered on all surveys. The scale was modified for the age 20 and 21 surveys, changing references to “school” to “school/work” to ensure the appropriateness of the question regardless whether the participant chose to pursue higher education and/or employment (in chi-squared tests, there were no significant differences in response to these questions whether the participant reported being a student or working). Analyses were restricted to participants who completed at least half the items on both scales in the grade 10 follow-up survey. To account for missing items, the total number of affirmative items was divided by the number of completed items (i.e., portion of answered items that were affirmative) and

multiplied by the total number of scale items (i.e., 12 alcohol items or 7 cannabis items). This corrected score was then standardized by dividing by the sample standard deviation.

In this analysis, the use of the term “misuse” is intended to reflect a pattern of use associated with the holistic outcomes described herein and not the changing legal definitions related to cannabis use. Furthermore, it is important to note that the American Academy of Pediatrics opposes any use of cannabis among children and adolescents (Committee On Adolescence Committee On Substance Abuse et al., 2015).

Covariates

At baseline, we asked participants to report personal demographics including: sex (male/female), whether they identified as Latino, were born in the US, and spoke English as their first language. Participants also reported parental characteristics, including whether their parents were born in the US, graduated high school, and were employed full-time, as well as completing the Index of Parenting Style (normal, authoritative, authoritarian, indulgent, neglectful) (Baumrind, 1966; Lamborn et al., 1991).

Data Analysis

We restricted the analytic sample to participants who responded to at least half of the misuse scale items at the grade 10 wave and used student t-tests to compare the baseline characteristics of students included in the analytic sample and those who were excluded (N=122, 11% exclusion). Using descriptive statistics to show temporal trends, we calculated the mean standardized cannabis and alcohol misuse scale score at each wave and graphed the mean proportion of item endorsements over time. We then conducted

logistic regression analyses to examine the relationship between misuse scale score at grade 10 and outcomes at age 21 (i.e., behavioral, mental health, academic, and social determinant). All models adjusted for the baseline covariates above (i.e., sex, ethnicity, birthplace, native language, parental birthplace, parental level of education, parental employment, and parenting style). All models used generalized estimating equations with a random effect for school to adjust for clustering of outcomes at the school-level. Within the analytic sample, there was 14% attrition from baseline to age 21. Examining missing, there was less than 5% missing among any single baseline covariate and less than 18% missing among any single age 21 outcome (problem substance use 18%, cigarette smoking 18%, vaping 18%, AUDIT 18%, high risk sex 14%, delinquent behaviors 14%, physical fighting 18%, flourishing 14%, depression 14%, anxiety 18%, PTSD 18%, English proficiency 12%, Math proficiency 12%, high school graduation 16%, 4-year college matriculation 16%, housing insecurity 16%, food insecurity 7%, transportation insecurity 16%, social isolation 16%, history of arrest 16%). Missing values were multiply imputed using a multivariable normal regression and 100 replicates (Allison, 2002; Schafer, 1997). Baseline covariates, age 16 misuse scale items, and outcomes recorded in age 20 and age 21 waves were included in the imputation model. Predicted probabilities were calculated as the probability of problem substance use at one standard deviation above the mean cannabis or alcohol misuse scale score, respectively. Primary analyses were performed using a threshold of significance of $\alpha < 0.05$. Sensitivity analyses were performed accounting for multiple comparisons using the Holm-Bonferroni method. STATA 17.0 (College Station, TX) was used for all analyses.

Results

In the RISE-Up study, 1270 students were enrolled at baseline and 1159 responded to the grade 10 survey at age 16. Of the 1159 respondents, 1148 (99%) answered at least half of the items on each of the cannabis and alcohol misuse scales in grade 10 and, of those, 1063 (93%) and 988 (86%) completed surveys at age 20 and 21 respectively.

Students who were excluded for not completing at least half of the misuse items were similar in sex, ethnicity, nativity, parental education, and parenting style to students who were included in the analytic sample. They were more likely to choose English as their native language (50% vs 40%), have at least one parent born in the US (38% vs 25%), and less likely to have at least one parent working full time (80% vs 88%). Table 1 summarizes student and parental characteristics at baseline. Cronbach's alpha for the Adolescent Cannabis Misuse Scale was calculated to be 0.76 and the correlation coefficient between the Adolescent Cannabis Misuse Scale and the Adolescent Alcohol Misuse scale was found to be 0.56.

Temporal trends

At grade 10, at least one cannabis misuse item was endorsed by 131 (11.4%) respondents. By age 20 and 21, this increased to 286 (24.9%) and 264 (23.0%) respondents respectively. Figure 1a and 1b demonstrate temporal trends in cannabis and alcohol misuse, respectively. The prevalence of nearly all cannabis misuse items increased with age. The overall increase in mean number of cannabis misuse behaviors was proportionally most attributable to increases in use alone, use at school, difficulty concentrating, and getting into trouble at home due to cannabis use. Doing something that the participant regretted, missing school, and getting into trouble at school due to cannabis use were largely stable over the study period.

At grade 10, at least one alcohol misuse item was endorsed by 182 (15.9%) respondents. Similar to cannabis misuse, mean alcohol misuse scores and prevalence of all alcohol misuse items increased with age (Figure 1b). The most commonly endorsed items were binge drinking, feeling sick due to alcohol consumption, trying to cut down on drinking, drinking alone, doing something that the participant later regretted due to alcohol, and getting into trouble at home due to alcohol. Of note, the Adolescent Alcohol Misuse Scale was not administered at age 20 and 21.

Early adulthood outcomes

Figure 2 summarizes the results of our primary analysis examining the association between the substance misuse scales at grade 10 and behavioral, mental health, academic, and social determinants of health outcomes at age 21. Within the behavioral outcomes, a one standard deviation greater cannabis misuse score was associated with 31% greater odds of problem substance use (OR 1.31, 95%CI[1.16, 1.49]), $p<0.001$) as well as greater odds of cigarette smoking (OR 1.20, 95%CI[1.07, 1.35], $p=0.003$), vaping (OR 1.20, 95%CI[1.07, 1.36], $p=0.003$), hazardous drinking (OR 1.29, 95%CI[1.14, 1.46], $p<0.001$), high risk sex practices (OR 1.36, 95%CI[1.18, 1.57], $p<0.001$), delinquent behaviors (OR 1.22, 95%CI[1.10, 1.37], $p<0.001$), and physical fighting (OR 1.32, 95%CI[1.21, 1.43], $p<0.001$). Except for cigarette smoking and vaping, all these associations were significant after adjusting for multiple comparisons using the Holm-Bonferroni correction. Similarly, the Alcohol Misuse Scale was associated with 32% greater odds of problem substance use (OR 1.32, 95%CI[1.18, 1.49], $p<0.001$) as well as cigarette smoking (OR 1.26, 95%CI[1.13, 1.40], $p<0.001$), vaping (OR 1.29, 95%CI[1.14, 1.46], $p<0.001$), hazardous drinking (OR 1.31, 95%CI[1.16, 1.47], $p<0.001$), high risk sex practices (OR 1.39, 95%CI[1.20, 1.60],

$p < 0.001$), delinquent behaviors (OR 1.29, 95%CI[1.14, 1.45], $p < 0.001$), and physical fighting (OR 1.24, 95%CI[1.11, 1.40], $p < 0.001$).

Among mental health outcomes, anxiety (OR 1.13, 95%CI[1.00, 1.28], $p = 0.049$) and PTSD (OR 1.20, 95%CI[1.09, 1.32], $p < 0.001$) were associated with the Cannabis Misuse Scale. The Alcohol Misuse Scale was associated with lower odds of flourishing (OR 0.81, 95%CI[0.70, 0.93], $p = 0.003$) and greater odds of depression (OR 1.19, 95%CI[1.06, 1.33], $p = 0.004$), anxiety (OR 1.22, 95%CI[1.06, 1.39], $p = 0.004$), and PTSD (OR 1.27, 95%CI[1.12, 1.43], $p < 0.001$). For both misuse scales, only associations with PTSD in early adulthood remained significant after correcting for multiple comparisons.

Higher standardized cannabis misuse scale score at grade 10 was associated with lower odds of English proficiency (OR 0.91, 95%CI[0.84, 1.00], $p = 0.044$), obtaining a high school diploma (OR 0.62, 95%CI[0.54, 0.71], $p < 0.001$), and lower odds of matriculating into a 4-year college (OR 0.85, 95%CI[0.76, 0.95], $p = 0.005$). Only odds of obtaining a high school diploma was significant at the corrected threshold of alpha. The Alcohol Misuse Scale was only associated with obtaining a high school diploma (OR 0.73, 95%CI[0.62, 0.85], $p < 0.001$) and this persisted at the more stringent threshold of alpha.

The Cannabis Misuse Scale at grade 10 was associated with greater odds of social isolation in early adulthood (OR 1.16, 95%CI[1.05, 1.28], $p = 0.004$) and having a history of arrest (OR 1.32, 95%CI[1.16, 1.51], $p < 0.001$). Similarly, the Alcohol Misuse Scale was associated with transportation insecurity (OR 1.15, 95%CI[1.02, 1.30], $p = 0.024$), social isolation (OR 1.19, 95%CI[1.06, 1.34], $p = 0.004$), and having a history

of arrest (OR 1.25, 95%CI[1.10, 1.44], $p < 0.001$). For both misuse scales, only history of arrest remained significant after correcting for multiple comparisons.

Individual Items

To identify the scale items most predictive of early adulthood problem substance use, we calculated the association between each item at grade 10 and problem substance use at age 21 (Table 2), adjusting for the same individual and parental covariates previously described. The cannabis misuse items most predictive of later problem substance use were: having trouble at school due to cannabis, using cannabis alone, and having used cannabis at school within the prior 30 days. The alcohol misuse items most predictive of later problem substance use were: drinking alcohol at school in the prior 30 days, missing school due to alcohol, getting into a fight or argument due to alcohol, doing something they regret due to alcohol, getting into trouble at home due to alcohol, and not studying due to alcohol. Of all items, only 1) doing something they regret due to cannabis and 2) feeling sick due to alcohol did not demonstrate a statically significant association with later problem substance use.

Predicted odds

Using our primary model, we found that a one standard deviation higher Adolescent Cannabis Misuse Scale score predicted a 4.9% higher odds of problem substance use in early adulthood and a one standard deviation higher Adolescent Alcohol Misuse Scale score predicted a 5.0% higher odds of problem substance use.

Discussion

Early identification of adolescent substance misuse is a cornerstone of preventing serious harm and holistically promoting adult health (Anthony, 2000; Gray & Squeglia,

2018; Kellam & Anthony, 1998). Using longitudinal data from an ongoing cohort of adolescents attending public schools in Los Angeles, we describe trends in cannabis misuse from adolescence to early adulthood using a novel Adolescent Cannabis Misuse Scale and compare findings with an established Adolescent Alcohol Misuse Scale (Edelen et al., 2009). The analyses identified patterns of cannabis use that show increasing prevalence with age (i.e., solitary cannabis use, use at school, having difficulty concentrating, and getting into trouble at home due to cannabis use) and those that remained stable with age (i.e., getting into trouble at school, missing school, or doing something regretful due to cannabis). The primary analyses found consistent correlations between higher scores on the Adolescent Cannabis Misuse Scale in middle adolescence and deleterious early adult outcomes including a 31% higher odds of problem substance use (i.e., 30-day use of illegal drugs, 30-day use of another person's prescription drugs to get high, and hazardous drinking as defined by an Alcohol Use Disorder Identification Test (AUDIT) score ≥ 8). Higher Adolescent Cannabis Misuse Scale score was also associated with additional behavioral outcomes (i.e., vaping, high risk sex practices, delinquent behaviors, physical fighting), mental health outcomes (i.e., PTSD), academic outcomes (i.e., high school graduation), and social determinants of health (i.e., social isolation, history of arrest).

While a handful of multi-item instruments have been used to assess adolescent cannabis misuse (Cannabis Use Disorder Identification Test, Cannabis Abuse Screening Test, CRAFFT), prior studies have only tested their cross-sectional associations with adolescent outcomes (Anaheim et al., 2008; Asbridge et al., 2014; Falck et al., 2012; Guitart et al., 2012; Legleye et al., 2007, 2011). We are not aware of any studies to date that have developed a multi-item instrument to assess adolescent cannabis misuse and

tested associations with multiple developmentally-relevant adult outcomes longitudinally. Our findings are similar to studies that use a frequency definition of misuse and observational studies that examine epidemiological associations with cannabis use more broadly. Early cannabis use is consistently associated with tobacco, alcohol, illicit substances, and even vaping (Hall, 2009; Hall & Degenhardt, 2009; Patton et al., 2007; Weinberger et al., 2021). More intensive cannabis use is associated with subsequent high risk sex practices such unprotected sex (Bryan et al., 2012; Hendershot et al., 2010). Observational studies find an association between frequency and age of initiation of cannabis use and delinquent behaviors (Chabrol & Saint-Martin, 2009; Fergusson et al., 1996). While little research has studied languishing and flourishing (Parker et al., 2018), chronic use has a low-moderate relationships with mental health outcomes of depression, anxiety, and post-traumatic stress disorder (Gobbi et al., 2019; Lee et al., 2018; McGee et al., 2000; Patton et al., 2002). Cannabis use has been linked in cross-sectional and longitudinal studies to a range of academic outcomes including lower probability of high school graduation (Lorenzetti et al., 2020; Lynskey & Hall, 2000). Finally, adolescent cannabis use is associated with a range of factors commonly described as social determinants of health as well as individual, family, and peer progenitors of those conditional states (Capaldi et al., 2022; Hyshka, 2013).

The findings also describe developmental shifts in individual items and their association with problem substance use. Using cannabis alone was the most commonly endorsed item, increased with time, and had one of the strongest associations with problem substance use in early adulthood. The value of this item is reinforced by its use on both the CAST (Legleye et al., 2011) and CRAFFT (Falck et al., 2012) screening

instruments (see Supplement 2 for comparison of screening instruments that are validated in adolescents). Of note, the analogous question on the Adolescent Alcohol Misuse Scale was not as strongly associated with later problem substance use. Getting into trouble at school due to cannabis and cannabis use at school also demonstrated relatively high prevalences that increased with age and had strong associations with problem substance use in early adulthood. CRAFFT asks about getting into trouble generally but neither the CAST nor CUDIT screening instruments have a similar question (Annaheim et al., 2008; Falck et al., 2012; Legleye et al., 2011). Missing school due to cannabis use was not as strongly associated with later problem substance use. Taking a regretful action is not an item asked on other substance use screening instruments (see Supplement 2) and was not significantly associated with later problem substance use in our analyses. However, regret was asked as part of the alcohol misuse scale and was significantly associated with later problem substance use. For this reason, we kept the item for comparison. Given some limited generalizability of our sample, future psychometric testing should examine the overall utility of including this item on the Adolescent Cannabis Misuse Scale. These findings contrast sharply with alcohol for which both use at school and missing school were less common but strongly associated with later problem substance use. Overall, higher scores on either substance misuse scale portend greater risk of negative long-term outcomes in adulthood. Further investigations are warranted to identify specific physiologic or sociocultural explanations for why some items elicited different responses when asked on the cannabis versus the alcohol misuse scales. The parallel findings also provide preliminary support for the new scale's construct validity, which might be further

supported in future longitudinal studies comparing the Adolescent Cannabis Misuse Scale to the CAST, CUDIT, or CRAFFT inventories.

Our findings should be considered with the following limitations. First, respondents may not have reported their behaviors accurately. We attempted to minimize risk of social desirability bias by employing a computer-assisted self-administered survey under scrupulous conditions of privacy, however, we did not collect biochemical or other corroborative evidence of cannabis use. To simplify calculation of the substance misuse scale scores and interpretability, we dichotomized item responses and outcomes. By dichotomizing we gave equal weight to each scale item but lost information along a continuum for items with multiple possible response levels. Greater precision may be gained by using analytic approaches that do not rely on dichotomization. Our primary outcome was a composite of four outcomes which can overestimate effects when one common outcome drives the effect. In this case, each of the four components was independently associated with the exposure and the decision to combine was to improve interpretability with a long roster of outcomes. While we examined illegal drug and prescription use in the last 30 days, greater specificity could be achieved using weekly or daily use. We restricted our analyses to those participants who had responded to at least half of the substance misuse items on each scale which could have introduced selection bias. This would have biased our results toward the null if students were leaving items blank due to social desirability bias. The results are not generalizable to all youth populations, particularly student groups who have not applied to charter schools, who living in other cities, or who come from other ethnic or cultural backgrounds. In particular, recreational cannabis for individuals 21 years or older was legalized in California in November 2016, which likely represents sociocultural shifts

that may differ in other states. Future work should compare our findings in California with states and countries that approach cannabis legalization differently. We have also not followed these individuals beyond early adulthood and although we found very similar results in successive waves (i.e., age 20 and age 21) we cannot extrapolate to older ages. We can however say that the greater risk of negative biopsychosocial outcomes identified at ages 20 and 21 years are themselves predictors of poor health trajectories and later life adversity. Lastly, while this analysis provides support for the Adolescent Cannabis Misuse Scale construct validity, additional work should further elucidate the instrument's psychometric properties.

The effect of the SARS-CoV-2 pandemic on the final two waves of data collection is difficult to determine. Data collection was performed using a computer-assisted technology in a private location of the student's choice which should have optimized privacy regardless if the survey was taken at school or home, however, we are unable to test this assumption. Despite national data suggesting stable prevalence of adolescent cannabis and alcohol use over this period,(Johnston et al., 2021; Miech et al., 2021), lockdowns and distancing may have biased upward some items (e.g., use alone), while artifactually reducing other items (e.g., getting in trouble at school). This would not alter our statistical models that were all based upon cannabis misuse in grade 10 but may have altered the trends depicted in Figure 1.

As our understanding of the natural history of substance use from youth into adulthood evolves, a public health approach to substance use prevention seeks to identify early markers of problematic use and weigh the many intersecting longitudinal consequences that may arise. Addressing early substance misuse may in fact have a greater impact on health and society than intervening upon established substance use

disorders (United States Department of Health and Human Services, Office of the Surgeon General, 2016). This work seeks to introduce a novel tool in that effort and situate it within a more holistic profile of negative life course consequences carrying great import at this developmental stage. As such, we hope these findings will be useful to researchers, adolescent health practitioners, and to public health policymakers who seek to identify and intervene upon substance use early to prevent serious harm and chronic disease.

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Disclosure of Interest

The authors report there are no competing interests to declare.

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Data availability statement

The raw data supporting the conclusions of this article will be made available upon request to the senior author by emailing MitchellWong@mednet.ucla.edu.

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