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Obesity vs. overweight status: differential predictions to poly-substance use in young adulthood

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Background: Though past research has identified links between higher weight status and substance use in young adulthood, prospective studies are scarce and mixed, the role of higher weight status on vaping is less clear, and little empirical work has examined differences between obesity vs. overweight on poly-substance use. The current study assessed the role of weight status on poly-substance use trajectories across young adulthood.

Methods: 1,303 young adults (20.5 ± 2.3 years; 63% female; 41% Latina/o/x, 30% Asian-American/Asian, 18% Caucasian/White) from a public, urban university were surveyed at six-month intervals from spring 2021 (W1) to spring 2023 (W5). Weight status was measured at W1 with body mass index (BMI) and categorized into obese ($BMI \geq 30.0$); overweight ($BMI 25.0-29.9$); healthy weight ($BMI 18.5-24.9$); and underweight ($BMI < 18.5$). Past 30-day use of nicotine vaping, cigarette smoking, cannabis vaping, combustible cannabis, cannabis edibles, and binge drinking across waves were used to identify poly-substance use trajectories with parallel growth mixture modeling (PGMM).

Results: Four trajectories were identified: Nicotine/Tobacco Users and Binge Drinkers (7.2%); Poly-Users (9.8%); Moderate Cannabis Users and Binge Drinkers (18.7%); and Non-Users (64.3%). Obese young adults (vs. healthy weight) had lower odds of belonging to the Nicotine/Tobacco Users and Binge Drinkers trajectory [$aOR = .24(.06-.99)$] vs. Non-Users trajectory. Overweight young adults (vs. healthy weight) had higher odds of belonging to the Moderate Cannabis Users and Binge Drinkers trajectory [$aOR = 1.94(1.25-3.03)$] vs. Non-Users trajectory.

Conclusions: Overweight young adults' higher odds vs. obese young adults' lower odds of belonging to poly-substance use trajectories suggest overweight young adults may be a key target group for poly-use public health initiatives. Poly-substance use differences between obese and overweight status indicate a greater need for specificity when evaluating relationships between higher weight status and substance use.

KEYWORDS

binge drinking, cannabis/marijuana, obesity, overweight, poly-substance use, tobacco/nicotine, vaping

1 Introduction

Obesity and poly-substance use are viewed as major public health concerns in young adulthood, as they are both linked to pervasive negative physical health outcomes, including earlier mortality risk, cancers, organ damage/failure, and cardiovascular illnesses (1–4), as well as mental health impairments (5–7). Among U.S. young adults, recent estimates report obesity (body mass index ≥ 30.0) prevalence at 35.5% (8) and overweight (body mass index 25.0–29.9) at 24.8% (9). Substance use among young adults for nicotine/tobacco (8.5% past 30-day cigarette smoking; 17.2% past 30-day nicotine vaping), cannabis (28.8% past 30-day marijuana; 13.9% past 30-day cannabis vaping), and alcohol (30.5% past two-weeks binge drinking) remains problematic (10). In a systematic review evaluating substance use among young adults across 20 studies, de Jonge et al. (11) found that about one-half to two-thirds of young adults were classified into some type of poly-substance use class (often co-occurring alcohol and tobacco use classes measured with lifetime, past 12 months, or past 30-day use). Given the high prevalence in young adulthood and marked negative health outcomes associated with obesity and poly-substance use, a growing literature has sought to examine whether higher weight status and substance use significantly co-occur in young adulthood. Recent studies suggest higher weight status and substance use share underlying mechanisms, such as dysregulation in similar brain reward pathways, depressive symptoms, and socio-contextual factors, which may contribute to their co-occurrence (12–14). Previous empirical work has reported both significant positive and negative associations between higher weight status and substance use (15–17). Significant gaps remain that limit our ability to know whether higher weight status is a predictor of poly-substance use in young adulthood. This study sought to address some of the current limitations of the literature by assessing the role of weight status on poly-substance use (nicotine/tobacco, cannabis, binge drinking) trajectories in young adulthood.

1.1 Prospective studies on higher weight status and poly-substance use

Prospective studies evaluating the role of higher weight status on poly-substance use are scarce. Available studies evaluating associations between higher weight status and different forms of substance use (including nicotine/tobacco, cannabis, and alcohol) have generally indicated positive associations between higher weight status and nicotine/tobacco use but not with cannabis or alcohol use. For example, earlier work using a nationally representative sample reported that obese or overweight vs. non-obese or overweight adolescents had a higher likelihood of belonging to a regular cigarette smoker class in young adulthood, but not to other substance use classes comprised of alcohol or cannabis use (18). Later using a sample of college students, Lanza et al. (19) found that obese vs. non-

obese status predicted higher likelihood of belonging to a dual cigarette/e-cigarette latent class, but again not to classes characterized by alcohol or cannabis use. In a community-based sample, Gearhardt et al. (20) indicated that obesity status predicted less problematic alcohol and illicit drug use vs. those in the normal weight category; however, nicotine dependence was significantly higher among obese and normal weight vs. overweight groups. The established relationship between nicotine and appetite suppression (21) may partly explain the positive association between higher weight status and nicotine/tobacco use; both adolescents and young adults frequently report using cigarette smoking and nicotine vaping as a weight management tool (22, 23). Even across different populations (community and college samples), ages (emerging adults <26 years and young adults 18–29 years), substance use indicators (e.g., nicotine dependence vs. past 30-day use), and time between weight status and substance use assessment (six months, adolescence to young adulthood), the link between obesity and nicotine/tobacco vs. other substances in young adulthood is fairly consistent. However, a closer look at differences between higher weight categories (obese vs. overweight) on substance use is less clear, which may be a result of some of these methodological differences.

1.2 Obesity vs. overweight status on substance use

Beyond the limited number of prospective studies assessing the relationship between higher weight status and poly-substance use, the current literature also has paid little attention to evaluating whether belonging to different higher weight status categories (obese vs. overweight) increases or decreases risk of substance use in young adulthood. Using CDC guidelines to classify obese and overweight status based on body mass index (BMI), a person is considered overweight if their BMI is between 25.0 to 29.9 and obese if their BMI is greater than or equal to 30.0 (https://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/). Though there is speculation that an inverse U-shaped relationship between BMI and substance use may exist (24), where overweight status may increase the likelihood of substance use compared to obesity status, an U-shaped relationship, particularly between BMI and nicotine/tobacco use, has also shown that obese smokers have greater frequency of use and nicotine dependence than non-obese smokers (25, 26). To add to the complexity of the relationship, most conceptual models on weight status and substance use date prior to the popularity of nicotine and cannabis vaping as well. Currently, only a few prospective studies have compared obese and overweight groups on substance use outcomes. Findings point to significant differential relationships, albeit with mixed results. In a prospective cohort study of college students, Lanza et al. (12) found that overweight status predicted higher likelihood of combustible cannabis use and binge drinking, whereas obese status predicted lower likelihood of nicotine vaping. In a population-based study of adolescents, Lee et al. (27), reported

that BMI trajectories characterized by overweight or obesity status (e.g., “overweight early increasing”, “obesity stable”) predicted higher likelihood of cigarette use, but only BMI trajectories characterized by overweight (“overweight late increasing”, “overweight increasing then decreasing”) predicted higher likelihood of e-cigarette use. As noted earlier, Gearhardt’s et al.’s (20) study using a community-based sample reported lower likelihood of problematic alcohol and illicit drug use among obese vs. normal weight groups, but a higher likelihood of nicotine dependence (smoking) among obese and normal weight groups compared to the overweight group.

Additional prospective studies are warranted to elucidate the relationship between obese vs. overweight status and substance use in young adulthood. Moreover, a focus on poly-substance use analyses that simultaneously includes nicotine/tobacco (cigarette smoking, nicotine vaping), cannabis (combustible cannabis, cannabis vaping), and alcohol (binge drinking) use is likely to inform previous mixed findings. Along with the utility of using prospective studies to identify differences between weight status categories on poly-substance use, closer consideration to the methods used across these studies may inform why mixed findings exist. The present dearth of research precludes knowing whether obese vs. overweight young adults would benefit from different approaches to substance use prevention and intervention. The implications for identifying overweight status as a predictor of poly-substance use are notable. Though obese status receives greater focus and resources across research, healthcare utilization, and public health policy compared to overweight status (28, 29), overweight status is significantly linked to similar physical [e.g., Type II diabetes, cancers, cardiovascular disease; (30, 31)] and mental (32, 33) health diseases and impairments as obese status. Building on past evidence suggesting overweight status is associated with substance use in ways that are different from obesity may help garner more attention and resources to a significant proportion of young adults.

1.3 The current study

Limitations on our knowledge regarding the role of higher weight status on substance use in young adulthood are three-fold: (1) there are a lack of prospective studies evaluating the risk of weight status on poly-substance use; (2) little empirical work has assessed differences between obese vs. overweight young adults on substance use; and (3) the role of obese vs. overweight status on poly-substance use trajectories is unclear. To address these limitations, the current study used data from a prospective cohort of young adults in college (five assessments across a two-year period; 2021–2023) to identify poly-substance trajectories (including nicotine vaping, cigarette smoking, cannabis vaping, combustible cannabis, and binge drinking) and assess whether weight status categories (obesity, overweight, underweight, healthy weight) predicted poly-substance use trajectories. Given the available evidence on weight status and poly-substance use in young adulthood (18, 20, 19), we expected

obese status to predict higher likelihood of belonging to a trajectory class characterized by tobacco/nicotine use, but not cannabis use or binge drinking. The few prospective studies assessing differential associations between obese and overweight groups on substance use (12, 20, 27) led us to hypothesize that there would be differences in poly-substance use trajectory membership between obese and overweight groups, though specific differences were not predicted due to past mixed findings. A greater understanding of the relationship between weight status and poly-substance use in young adulthood will be beneficial for informing public health efforts aimed at combating two of the most critical public health issues facing young adults today—substance use and obesity/overweight.

2 Methods

2.1 Participants and procedure

Participants were 1,303 young adults from a prospective cohort study conducted at a large, urban public university in Southern California. With close to two-thirds (61.4%) of U.S. high school graduates attending college (34), and evidence that undergraduates are at high risk for both poly-substance use and obesity (35, 36), college students are an increasingly valuable population for understanding development of co-occurring health-risk behaviors. During Spring 2021, 93 classes were randomly selected for participant recruitment from all undergraduate classes with meeting times. Of the 93 randomly selected classes, 67 (72.0%) instructors agreed to a 10-minute class recruitment visit. Class visits (which took place online due to COVID-19 restrictions) were conducted by the PI from late January to late April 2021. Following the study presentation, eligible (≥ 18 years, currently enrolled undergraduate) and interested participants were able to review the informed consent online. Once a student completed and submitted the informed consent form online, the PI individually emailed the participant an online survey link and unique verification code. Participants completed a 15 min health behavior survey that included questions on eating habits, exercise, weight status, substance use, mood, personality, and social relationships; surveys were completed in spring 2021 and then at six-month intervals (fall 2021, spring 2022, fall 2022, and spring 2023). To avoid identifying information being collected within the survey, the unique verification code was used to link a participant’s survey with their informed consent. Participants received a \$15 Amazon e-giftcard for each survey. All study protocol was approved by the California State University, Long Beach Institutional Review Board.

Of 2,651 students targeted in 67 randomly selected classes, 1,361 students (51.3%) participated in the study. Participants between 18 and 29 years at baseline (spring 2021) were selected for current study analyses ($N = 1,303$; 95.7% of total sample). Retention rates among the analytic sample were: 1,085 (83.3%) at six-month follow-up; 982 (75.4%) at one-year follow-up; 890 (68.3%) at 18-month follow-up; and 888 (68.2%) at two-year

follow-up. The average age of participants was $M = 20.52$ ($SD = 2.29$) years. The sample closely aligned with the gender and race/ethnicity composition of the institution's undergraduate population. Participants in the sample included (university 2020–2021 academic year statistics in parentheses): 62.5% (59.4%) female, 34.8% (40.6%) male; 2.5% transgender or gender variant/non-binary/non-conforming; 41.2% (47.9%) Hispanic/Latino/a/x, 30.3% (25.3%) Asian-American/Asian, 18.0% (16.1%) Caucasian/White, 1.8% (3.7%) African-American/Black, 7.5% (4.6%) Multiracial; 0.8% (0.2%) Pacific Islander/Native Hawaiian, and 0.1% (0.1%) Native American/Alaskan Native. About two-thirds (63.8%) reported their parents attended some college or a higher level of education.

3 Measures

3.1 Weight status

Participants self-reported height and weight at baseline (Wave 1), which was used to calculate body mass index (BMI; $\text{weight}(\text{lbs})/[\text{height}(\text{in})^2 \times 703]$). Based on U.S. Centers for Disease Control (CDC) recommendations (https://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/), participants were categorized into one of four weight status categories: obese (BMI ≥ 30.0); overweight (BMI 25.0–29.9); healthy weight (BMI 18.5–24.9); and underweight (BMI < 18.5). Dummy coding for the multinomial weight status variable was created with healthy weight as the reference category (*obese vs. healthy weight, overweight vs. healthy weight, underweight vs. healthy weight*).

3.2 Substance use

Past 30-day use of nicotine vaping, cigarette smoking, cannabis vaping, combustible cannabis, cannabis edibles, and binge drinking were assessed with participant self-report at each wave, from spring 2021 (W1) to spring 2023 (W5). The exception was cannabis edibles, which was not measured until fall 2021 (W2). Questions were derived from the National Institute of Drug Abuse (NIDA) Clinical Trials Network Tobacco, Alcohol, Prescription Medications, and Substance Use/Misuse (TAPS) assessment, which validated substance use questions on an adult population-based sample (37), as well as the Health & Happiness Study, a population-based prospective cohort study of adolescents and young adults in Southern California that has published vast studies on youth tobacco/nicotine and cannabis use (38, 39). For each type of substance, participants were first asked about lifetime use: “Have you ever used a vaporizer to vape nicotine (e.g., Puff Bar, JUUL, Box mod)?”; “Have you ever smoked a cigarette?”; “Have you ever used a vaporizer to vape cannabis (e.g., Pax Era, Heavy Hitters, Dosist, Kandypens)?”; “Have you ever smoked cannabis (marijuana, weed, pot)?”; “Have you ever consumed a cannabis (marijuana) edible?”; “Have you ever consumed more than 5 alcoholic drinks in one sitting (if you are a man) or 4 alcoholic

drinks in one sitting (if you are a woman)?”. If participants reported lifetime use for a specific substance, they were asked a corresponding question on past 30-day use: (e.g., “In the past 30 days have you vaped nicotine?”; “In the past 30 days have you consumed a cannabis edible?”). Dichotomous variables for past 30-day use (*past 30-day use vs. no past 30-day use*) were created for each substance use product at each wave.

3.3 Sociodemographic covariates

Age, gender, race/ethnicity, and parent highest education were self-reported at baseline. Participants reported their age (in years), gender (female, male, transgender female, transgender male, gender variant/non-binary/non-conforming), race/ethnicity (African-American/Black, Asian-American/Asian, Caucasian/White, Hispanic/Latino/a/x, Native American/Alaskan Native, Pacific Islander/Native Hawaiian, Multi-racial, and other), and highest parent education (less than some high school, some high school, graduated from high school, some college, graduated from college, earned graduate degree). Gender was recoded as *male vs. non-male* (instead of male vs. female) to include all participants, including transgender and non-binary, in analyses. Race/ethnicity was recoded into dummy variables (*Asian American/Asian vs. non-Asian American/Asian*) for racial/ethnic groups representing $\geq 10\%$ of the sample (89.2% of the total sample was comprised of Hispanic/Latino/a/x: 41.4%, Asian American/Asian: 29.6%; and Caucasian/White: 18.2%). Highest parent education was recoded into a dichotomous variable ($\geq \text{some college vs. } < \text{some college}$).

3.4 Analysis plan

We used parallel process growth mixture modeling (PGMM) to estimate poly-substance use trajectories. Each substance use product was simultaneously modeled as a unique growth process producing 3 growth factors (i.e., intercept, linear and quadratic slopes [rate of change across the five time points, (40, 41)]). The model estimated trajectory groups based on covariation across the six distinct sets of growth factors (i.e., one set of growth factors—intercept, linear, quadratic—per product, 18 total factors). GMM uses a data-driven approach to estimate trajectory classes; classes are not identified *a priori* but rather derived from the unobserved heterogeneity in the population. An increasing number of trajectory classes were estimated until an optimal model was identified using statistical fit indices, including the Bayesian Information Criterion [BIC; (42)] and Lo-Mendell Rubin Likelihood Ratio Test [LMR LRT; (43)], as well as class interpretation and parsimony. Full information maximum likelihood was used to account for missing data. Covariates of identified trajectories were evaluated within the PGMM framework using a validated 3-step approach to account for classification error (44). After the best fitting class model was chosen, a most likely latent class variable was created using the latent class posterior probabilities. Logits reflecting the classification uncertainty rate were applied to account for measurement error in the most likely class variable. The most

likely class variable was then used to assess covariates of trajectory membership. Analyses were conducted with Mplus 8.11 (45).

4 Results

4.1 Descriptive statistics

Table 1 presents demographic characteristics and weight status at Wave 1, as well as past 30-day substance use prevalence at each wave. Just over a half of participants were classified as healthy weight (57.6%). A third of the sample were obese (13.3%) or overweight (20.4%); 6.0% were underweight. Across all waves, binge drinking had the highest past 30-day prevalence (13.0%–16.8%) while cigarette smoking had the lowest past 30-day prevalence (2.1%–2.8%).

4.2 Substance use trajectories

4.2.1 Model selection

Model fit was evaluated across an increasing number of trajectory classes. Based on statistical indices (Table 2), class

interpretability, and parsimony, the four-class model was identified as best-fitting the data. The LMR LRT indicated that the four-class model was ideal; the LMR LRT was not significant past the five-class solution. Although the four-class model did not have the lowest BIC or adjusted-BIC values, the BIC values leveled off between the three- and four-class models. This leveling-off, along with consideration of class interpretation (distinct and homogenous classes) and parsimony, resulted in identifying the four-class model as optimal. Figure 1 presents the probability of past 30-day use of each substance use product for each identified trajectory.

4.2.2 Identified trajectories

The Nicotine/Tobacco Users and Binge Drinkers trajectory (7.2%) was characterized by relatively high probability of nicotine/tobacco use and binge drinking, but low probability of cannabis use (Figure 1A). Nicotine vaping probabilities across waves (60.0%–82.5%), as well as binge drinking (48.7%–59.4%) were prominent. Comparatively, cigarette smoking probabilities were low across waves (19.3%–21.8%), but still higher within this trajectory than any other trajectory class.

TABLE 1 Demographic characteristics, weight status, and substance use ($N = 1,303$).

	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5
Demographics	N(%) or Mean $\pm$ SD				
Age (years)	20.52 $\pm$ 2.29				
Gender					
Female	815 (62.5%)				
Male	454 (34.8%)				
Non-Binary	26 (2.0%)				
Transgender	6 (0.6%)				
Ethnicity/Race					
African-American/Black	24 (1.8%)				
Asian-American/Asian	395 (30.3%)				
Caucasian/White	235 (18.0%)				
Hispanic/Latino/a/x	537 (41.2%)				
Native American/Alaska Native	1 (0.1%)				
Pacific Islander/Native American	11 (0.8%)				
Multiracial	98 (7.5%)				
Parent Highest Education Level					
$\geq$ Some college	831 (63.8%)				
<Some college	469 (36.0%)				
Weight Status ^a					
Obese	173 (13.3%)				
Overweight	266 (20.4%)				
Healthy Weight	751 (57.6%)				
Underweight	78 (6.0%)				
Nicotine Vaping ^b	113 (8.7%)	109 (8.4%)	100 (7.7%)	94 (7.2%)	85 (6.7%)
Cigarette Smoking ^b	35 (2.7%)	37 (2.8%)	29 (2.2%)	31 (2.4%)	28 (2.1%)
Cannabis Vaping ^b	163 (12.5%)	138 (10.6%)	123 (9.4%)	116 (8.9%)	105 (8.1%)
Combustible Cannabis ^b	180 (13.8%)	151 (11.6%)	137 (10.5%)	113 (8.7%)	104 (8.0%)
Cannabis Edibles ^{b,c}		103 (7.9%)	100 (7.7%)	87 (6.7%)	78 (6.0%)
Binge Drinking ^b	177 (13.6%)	219 (16.8%)	179 (13.7%)	175 (13.4%)	169 (13.0%)

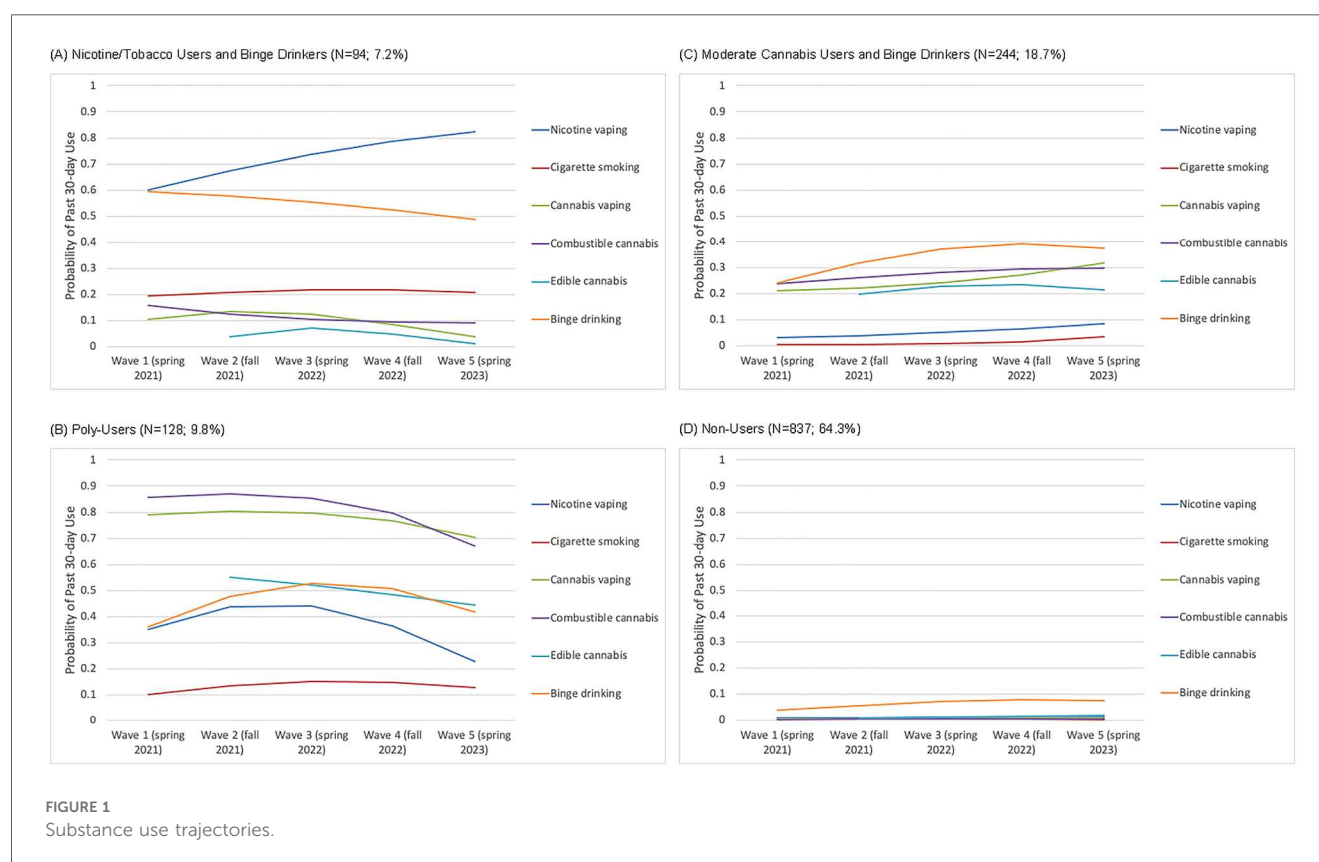
^aWeight status was estimated using the U.S. Centers for Disease Control (CDC) recommendations: obese (BMI ≥ 30.0); overweight (BMI 25.0–29.9); healthy weight (BMI 18.5–24.9), and underweight (BMI < 18.5).

^bPast 30-day use (yes/no) was used to measure substance use across each wave.

^cCannabis edibles was not reported until Wave 2.

TABLE 2 Model fit indices for substance use trajectories.

Trajectory#	AIC ^a	BIC ^b	Adjusted BIC ^c	LMR LRT p -value for $k-1$ ^d	Entropy
1	19,871.67	19,964.76	19,907.58	N/A	N/A
2	15,616.05	15,807.40	15,689.87	<.0001	.92
3	14,972.48	15,262.09	15,084.20	<.01	.91
4	14,564.04	14,951.91	14,713.67	<.05	.88
5	14,347.64	14,833.77	14,535.18	.3216	.82
6	14,255.12	14,839.52	14,480.57	.2398	.82

^aAIC, akaike information criterion.^bBIC, bayesian information criterion.^cSample-size adjusted Bayesian information criterion.^dLMR LRT, Lo-Mendell-Rubin likelihood ratio test, p -value for $k-1$ refers to significant improvement in model fit between the class (k) and the class preceding it ($k-1$).FIGURE 1
Substance use trajectories.

The Poly-Users trajectory (9.8%) reflected high probability of use for various tobacco/nicotine and cannabis products, as well as binge drinking across waves (Figure 1B). Probability of use was highest for combustible cannabis (67.1%–86.9%) and cannabis vaping (70.2%–80.5%) across waves. Edible cannabis remained at about 45%–55% across the study period. A significant quadratic decrease was identified for both binge drinking (quadratic = $-.14$, $p < .01$) and nicotine vaping (quadratic = $-.17$, $p < .01$). Binge drinking increased from Wave 1 (36.2%) to Waves 2 (47.6%) and 3 (52.6%), but then decreased at Waves 4 (50.6%) and 5 (41.8%). Similarly, nicotine vaping increased from Wave 1 (35.0%) to Waves 2 (43.7%) and 3 (44.2%), but then decreased at Waves 4 (36.4%) and 5 (22.6%). Cigarette smoking probability was lower than other substance use products and held stable across waves (10.1%–15.1%).

The Moderate Cannabis Users and Binge Drinkers trajectory (18.7%) was characterized by moderate probability of cannabis use and binge drinking and low probability of tobacco/nicotine use (Figure 1C). Probability of all cannabis products (vaping, combustible, edible) ranged between 20%–32% across waves. Binge drinking probability was slightly higher; a significant rate of change (slope = $.46$, $p < .05$) was found for binge drinking across waves (24.0%–39.0%). Probability of nicotine vaping and cigarette smoking was relatively low (<10%) across waves.

Non-Users (64.3%) comprised the largest trajectory class. This trajectory was comprised of no or very low substance use across waves (Figure 1D). Probability of tobacco/nicotine use and cannabis use was negligible across waves (<2%). Binge drinking probability was also low (<8%) across waves; a significant rate of

change (slope = .49, $p < .05$) was found for binge drinking across waves (3.7%–7.6%).

4.3 Correlates of substance use trajectories

Sociodemographic and weight status covariates were added to the parallel process GMM to determine the odds of trajectory membership in each of the three substance-using trajectories vs. the Non-Users trajectory (Table 3). Obese young adults (vs. healthy weight) had lower odds of belonging to the Nicotine/Tobacco Users and Binge Drinkers trajectory [aOR = .24(.06–.99)] vs. Non-Users trajectory. Overweight young adults (vs. healthy weight) had higher odds of belonging to the Moderate Cannabis Users and Binge Drinkers trajectory [aOR = 1.94(1.25–3.03)] vs. Non-Users trajectory. Underweight status was not a significant covariate of any poly-substance use trajectory.

Older participants had higher odds of belonging to the Nicotine/Tobacco Users and Binge Drinkers [aOR = 1.27(1.11–1.35)] and Poly-Users [aOR = 1.11(1.02–1.20)] trajectories vs. the Non-Users trajectory. Males had lower odds of belonging to the Moderate Cannabis Users and Binge Drinkers trajectory [aOR = .62(.42–.92)] vs. the Non-Users trajectory. Asian/Asian-American young adults had lower odds of belonging to the Poly-Users [aOR = .44(.21–.92)] and Moderate Cannabis Users and Binge Drinkers [aOR = .42(.22–.79)] trajectories compared to the Non-Users trajectory. Latina/o/x young adults had lower odds of belonging to the Nicotine/Tobacco Users and Binge Drinkers trajectory [aOR = .24(.11–.56)] vs. the Non-Users trajectory.

5 Discussion

The current study advanced understanding of the relationship between weight status and poly-substance use during young

adulthood by identifying trajectories of tobacco/nicotine, cannabis, and alcohol poly-use and assessing the role of weight status on trajectory membership. All three identified substance-using trajectories (Nicotine/Tobacco Users and Binge Drinkers, Poly-users, Moderate Cannabis Users and Binge Drinkers) were characterized by some form of poly-use, highlighting the importance of integrative substance use approaches for prevention and intervention during this critical developmental period for substance use. Compared to healthy weight status, obesity status predicted lower, not higher, odds of belonging to a substance-using trajectory (Nicotine/Tobacco Users and Binge Drinkers). On the other hand, overweight status (vs. healthy weight) predicted higher odds of belonging to a substance-using trajectory (Moderate Cannabis Users and Binge Drinkers). The marked difference between obese and overweight young adults' risk of poly-substance use suggests greater specificity is needed when evaluating the relationship of higher weight status on substance use.

Using a parallel approach to GMM, this study identified four distinct underlying subpopulations of tobacco/nicotine, cannabis, and alcohol use: (1) Non-Users (64.3%); (2) Moderate Cannabis Users and Binge Drinkers (18.7%); (3) Poly-Users (9.8%); and (4) Tobacco/Nicotine Users and Binge Drinkers (7.2%). These developmental patterns indicate a significant proportion of young adults in this study—close to 40%—engaged in some form of poly-substance use. This proportion of poly-substance use is in line with de Jonge et al.'s (11) systematic review that reported one-half to two-thirds of young adults were engaged in poly-use. It is notable that all three poly-substance use trajectories were characterized by a high probability of binge drinking. Though current binge drinking prevalence remains high among young adults [30.5%; (10)], the rise of novelty tobacco/nicotine and cannabis products (nicotine vaping, cannabis vaping, cannabis edibles, etc.) and significant attention paid to ever-evolving tobacco/nicotine and cannabis legislative

TABLE 3 Estimated adjusted odds ratios (aOR) of substance use trajectory membership.

	Nicotine/Tobacco Users and Binge Drinkers	Poly-Users	Moderate Cannabis Users and Binge Drinkers
Reference Trajectory: Non-Users			
Covariates	aOR (95% CI)	aOR (95% CI)	aOR (95% CI)
Age (years) at baseline	1.27 (1.11–1.35)***	1.11 (1.02–1.20)*	1.05 (.97–1.14)
Male vs. non-male ^a	1.01 (.60–1.69)	.90 (.58–1.39)	.62 (.42–.92)*
Race/Ethnicity ^c			
Asian/Asian-American vs. non-Asian/Asian-American	.47 (.22–1.01)	.44 (.21–.92)*	.42 (.22–.79)**
Latina/o/x vs. non-Latina/o/x	.24 (.11–.56)**	.67 (.33–1.37)	.64 (.35–1.17)
White/Caucasian vs. non-White/Caucasian	.92 (.42–1.99)	1.22 (.59–2.52)	.85 (.44–1.65)
Highest parental education level ^b	.79 (.46–1.37)	1.42 (.86–2.33)	1.34 (.87–2.06)
Weight Status ^c			
Obese vs. healthy weight	.24 (.06–.99)*	.92 (.49–1.74)	1.15 (.66–2.01)
Overweight vs. healthy weight	1.49 (.82–2.68)	1.35 (.79–2.31)	1.94 (1.25–3.03)**
Underweight vs. healthy weight	.42 (.09–1.84)	.80 (.31–2.04)	.66(.26–1.67)

^aMales compared to females and other gender identities (non-binary, transgender).

^bHighest parent education coded as $\geq$ some college vs. $<$ some college.

^cRace/ethnicity and weight status modeled as dummy-coded variables.

* $p < .05$; ** $p < .01$; *** $p < .001$.

policies (e.g., e-cigarette flavor bans, cannabis legalization) has potentially undermined public health concerns related to young adult binge drinking. This is concerning as recent studies, including systematic reviews and meta-analyses, show young adult binge drinking is linked to structural and functional abnormalities in brain regions involved in self-regulation and reward processing, which increases the likelihood of risky sexual behavior, poly-substance use, and interpersonal violence (46–49). Overall, the current study finds that focus on poly-substance use vs. single-substance use is warranted to prevent problematic substance use patterns in young adults.

In addition to addressing gaps in the young adult substance use literature related to longitudinal measurement of poly-use involving tobacco/nicotine, cannabis, and binge drinking, a key aim of the study was to add to the small but burgeoning knowledge base on the role weight status plays on substance use in young adulthood. Though our hypothesis that obese vs. healthy weight young adults would have a higher likelihood of belonging to tobacco/nicotine-using trajectories was based on past studies indicating obesity status predicted tobacco/nicotine use in young adulthood (18–20), the lack of prospective studies, especially on nicotine vaping, makes the unexpected finding that obese status (vs. healthy weight) predicted lower likelihood of belonging to the Nicotine/Tobacco Users and Binge Drinkers vs. Non-Users trajectory less surprising. Moreover, the finding that overweight vs. healthy weight young adults had a higher likelihood of belonging to the Moderate Cannabis Users and Binge Drinkers vs. Non-Users trajectory suggests overweight young adults may be a key target group for anti-cannabis and binge drinking public health initiatives. There is already some evidence indicating overweight young adults are vulnerable to combustible cannabis and binge drinking (12). Though this study lends some evidence for the inverse U-shaped relationship between weight status and substance use posited by Amiri and Behnezhad (24), it is important to note underweight vs. healthy weight was not associated with higher or lower risk of poly-substance use. The notable differences between obese and overweight young adults suggest greater specificity is needed when evaluating relationships between weight status and substance use.

Obese and overweight young adults' differential poly-substance use risk suggest obese vs. overweight categories have distinct shared underlying mechanisms with poly-substance use. For example, different socio-environmental contexts between obese and overweight young adults may explain why overweight young adults were at higher risk of poly-substance use vs. healthy weight young adults, but obese young adults were not. Overweight young adults may have an easier time than obese young adults socializing with peers, but their vulnerability to being socially excluded may influence greater risk of poly-substance use to appear cool and engaged in what they believe is the normative peer social context (50). It is also possible that a significant proportion of overweight young adults in this study recently shifted from healthy to unhealthy weight status, as increased weight is a common experience among college students (51). Potentially these overweight young adults may be engaging in poly-substance use as a coping mechanism in response to recent

body weight increases (52–54). Conversely, obese young adults' opportunities to engage in poly-substance use, which often take place at social events with peers during the college years (55, 56) may be more limited because obese young adults face greater challenges (e.g., social stigma, marginalization) participating in social and recreational activities compared to overweight young adults (57, 58). Moreover, it is possible that the food-drug competition hypothesis (20, 59, 60) played a role in obese young adults' lower risk of poly-substance use compared to healthy weight peers. Obese individuals' greater vulnerability towards over-eating compared to other weight categories (61) may protect against poly-substance use as the neural reward pathways shared by food and drugs are saturated with over-eating behaviors.

The current study also used a sample that was largely racial/ethnic minority (82.0%) and female (62.5%), which may explain differences with previous studies evaluating race/ethnicity and gender across poly-substance use trajectories. Unlike two recent studies indicating White vs. non-White participants had higher odds of belonging to a poly-substance use vs. a non-users trajectory (62, 78), this study did not find Caucasian/White (vs. non-Caucasian/White) young adults at higher risk of membership in a poly-substance use vs. non-users trajectory. A lower likelihood of Asian/Asian-American vs. non-Asian/Asian-American young adults belonging to the Poly-Users and Moderate Cannabis Users and Binge Drinkers vs. Non-Users trajectory corroborates Cho et al.'s (63) study that showed Asian (vs. Hispanic) adolescents had lower odds of belonging to an early initiation poly-use trajectory (vs. non-users). We also found that Latina/o/x vs. non-Latina/o/x young adults had lower odds of belonging to the Nicotine/Tobacco and Binge Drinkers vs. Non-Users trajectory. Males vs. non-males lower odds of belonging to the Moderate Cannabis Users and Binge Drinkers vs. Non-Users trajectory aligns with a past finding indicating males vs. females had lower odds of belonging to a Young Adult-Onset Poly-Substance/Poly-Product Users vs. non-users trajectory (64), though another poly-substance trajectory study reported males (vs. females) had a higher likelihood of belonging to a poly-substance use trajectory vs. non-users trajectory, as well as earlier vs. later poly-use (65). Potentially the higher risk of overweight and obesity status among Latina/o/xs and females, and lower risk among Asian/Asian-Americans (36, 66, 67) may have contributed to the racial/ethnic and gender differences observed in this sample, which was predominately Asian/Asian-American, Latina/o/x and female.

Of course, limitations of this study need to be considered when drawing conclusions. The use of a sample specific to Southern California limits generalizability of findings to other regions; however, a regionally-specific sample increases the likelihood that participants were exposed to similar tobacco/nicotine, cannabis, and alcohol regulatory policies and trends during assessment. The sample attrition rate grew across timepoints and was close to one-third at the conclusion of the study; however, full information maximum likelihood enabled participants with at least one wave of data to be analyzed. Though the study relied on self-report of past 30-day substance use, self-report remains the most common method of measuring substance use behaviors. In addition, we recognize that measuring substance use with a binary (yes/no) indicator

compared to frequency of use did not allow us to determine whether poly-substance use trajectory classes reflect problematic use. The study also relied on self-reported vs. directly measured BMI. Although directly measured vs. self-reported height and weight is ideal, past research has indicated that self-reported BMI has high concordance with directly measured BMI among adolescents and young adults (68–70). That said, we recognize that BMI, whether directly measured or self-reported, is not as accurate an indicator as anthropometric measures (e.g., visceral adiposity, waist circumference, skinfold thickness) for evaluating healthy vs. unhealthy status (70, 79, 80), and additional research on this topic using anthropometric measures is needed. Moreover, only weight status at baseline was included in the analysis; thus, we do not know the impact between acute vs. chronic higher weight status. Additionally, though most prospective studies among adolescent and young adult populations have focused on the pathway from higher weight status to substance use, there is evidence that substance use, specifically cigarette smoking and binge drinking, predict higher BMI, overweight, and obese status in adolescents and young adults (71–74). Future research assessing bidirectional associations between poly-substance use and weight status is warranted to further inform the underlying pathways to co-occurring substance use and weight status health-risks among young adults. We also note that our proxy for SES, parent education, did not allow for more meaningful interpretations of the role SES has on poly-substance use trajectories. Additionally, we did not consider hypothesized underlying mechanisms of both weight status and substance use, such as depressive symptoms, social context, and biobehavioral markers of shared reward pathways (12–14). Though our primary aim in the current study was addressing gaps in the literature related to the use of prospective studies, poly-substance use measures, and comparison of weight status categories, moving forward with the current findings can inform which underlying processes may best explain the significant associations identified.

Despite these limitations, this study advances knowledge on the relationship between weight status and substance use by identifying distinct differences between higher weight status categories' risk of poly-substance use trajectories in young adulthood. Obese and overweight young adults, often viewed as more similar than different in relation to physical and psychosocial consequences, reported unique associations with substance use. Overweight (vs. healthy weight) young adults had a higher likelihood of belonging to a Moderate Cannabis Users and Binge Drinkers vs. Non-users trajectory, whereas obese (vs. healthy weight) young adults unexpectedly had a lower likelihood of belonging to a Tobacco/Nicotine Users and Binge Drinkers vs. Non-users trajectory. The findings highlight a need to better understand the epidemiological distinctions between obese and overweight young adults' poly-substance use. A more nuanced view of the role weight status plays on substance use in young adulthood is likely to improve current efforts to reduce co-occurring health-risks earlier in the lifespan. Though obese status earns significantly more research and clinical attention than overweight status, overweight young adults' greater risk of poly-substance use compared to healthy weight

peers suggests they may be a key target group for anti-poly-substance use public health initiatives. Moving forward, identifying underlying risk processes and pathways linking overweight to poly-substance use in young adulthood, which may involve an interaction between peer context and internalizing symptoms different from obese young adults, is warranted. Additionally, the significant proportion of poly-substance use vs. single-substance use observed in this study indicates poly-substance use may be the normative pattern of tobacco/nicotine, cannabis, and binge drinking among young adults. Greater attention to developing comprehensive, integrative approaches to substance use health services that reflect the high prevalence of poly-substance use is critical moving forward, especially as young adults engaged in poly-substance use are at greater risk of deleterious health outcomes compared to single-substance users, including cognitive deficits, mental health impairments, and greater substance dependence (75–77). Further research on the determinants and health consequences of poly-substance use is warranted to not only understand key targets for intervention, but also policy priorities for reducing poly-substance use in young adulthood.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Institutional Review Board, California State University, Long Beach. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

HL: Visualization, Resources, Formal analysis, Funding acquisition, Project administration, Writing – original draft, Validation, Data curation, Investigation, Supervision, Conceptualization, Methodology, Writing – review & editing. KW: Writing – review & editing, Writing – original draft. LS: Writing – review & editing, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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