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Original Article

The Transition of Sociodemographic and Substance Abuse Characteristics, Pairwise Co-occurrences and Factors Associated with Polysubstance Use Among US Adolescents and Young Adults

Md Tareq Ferdous Khan[1*], Shrabanti Mazumder[2], Md Habibur Rahman[3], Most Alina Afroz[4], Humayun Kiser[5], Mohammad Alfrad Nobel Bhuiyan[6]

[1]Department of Mathematics and Statistics, Cleveland State University, Cleveland, OH, USA
[2]Division of Biostatistics and Bioinformatics, Department of Environmental and Public Health Sciences, University of Cincinnati College of Medicine, Cincinnati, OH, USA
[3]Department of Statistics, Jahangirnagar University, Savar, Dhaka, Bangladesh
[4]Office of Research, LSU Health Sciences Center-Shreveport, Shreveport, Louisiana, USA
[5]Department of Statistics, Comilla University, Comilla, Bangladesh
[6]Department of Medicine, LSU Health Sciences Center-Shreveport, Shreveport, Louisiana, USA

*__Corresponding Author:__ Md Tareq Ferdous Khan, Email: m.f.khan20@csuohio.edu

Abstract

Background: Substance abuse by adolescents and young adults is a major public health issue. This study aimed to (i) show the transition of sociodemographic and substance abuse characteristics from 1992 to 2017 among US adolescents and young adults, (ii) evaluate the likelihood of co-occurrence of substances, and (iii) identify significant sociodemographic characteristics in association with polysubstance abuse.

Methods: This study extracted data for adolescents and young adults from 1992 and 2017 Treatment Episode Data Set-Admission (TEDS-A) datasets. The extracted sample included 337 858 admissions in 1992 and 333 322 in 2017.

Findings: Both years experienced significant admissions. A significant transition in 2017 compared to 1992 was evident in education, living status, and ethnicity. Substance-specific transition showed alcohol was dominant in 1992, while marijuana/hashish was dominant in 2017. Also, heroin, other opiates/synthetics, and methamphetamine experienced an increase, while cocaine/crack decreased. The pairwise co-occurrences exhibited a considerable variation in the likelihood of using one substance given another one. The odds ratios (ORs) obtained from generalized ordered logit models showed significantly higher odds of one or more substances with age, while education showed the opposite scenario. A mixed effect of gender was evident in 1992, whereas females were significantly less likely with one or more substances than males in 2017. Other significant vulnerable groups were those not in the labor force, homeless, white, and Mexican Americans.

Conclusion: The findings may help to understand the overall changes between 1992 and 2017 and take necessary measures to reduce the burden of this public health problem.

Keywords: Substance abuse, Sociodemographic transition, Polysubstance co-occurrence, Logistic regressions, Odds ratio

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Introduction

Epidemiological studies have shown that experimentation with substances and the beginning of their use mainly occur during adolescence and young adult time.[1] A study on Monitoring the Future Survey (MFS) by Johnston et al[2] showed that around 48.2% of 12 graders report using an illicit drug at some point in their lives, and 41.2% of them report using an illicit drug had consumed alcohol, while 19.2% smoked tobacco cigarettes. The numerous consequences of substance abuse (including feeding and eating disorders,[3] medical consequences,[4] improper behaviors,[5,6] impulsivity,[7] and symptomatology, which resembles mental illness,[8,9] cognitive disorders,[10] the spread of contagious disease,[11] the suicidal tendency,[12] criminal offenses,[13] economic loss,[14] etc.) make it a significant public health issue. Hedegaard et al[15] of the National Center for Health Statistics (NCHS) showed that the number of deaths of all ages due to overdose in

the United States in 2018 was 67 367, which declined 4.1% from 2017 but increased around 75.6% from 2010.

A recent study by Mazumder et al[16] exhibited the US national-level trend for commonly used substances. They showed an overall increase in admissions due to methamphetamine, heroin, and marijuana/hashish from 1992 to 2017 and a slight decrease in cocaine/crack and alcohol. While methamphetamine and heroin revealed a monotonic increase, the other 3 substances showed a significant upturn from 2016. The study was focused on admissions of all ages rather than the cohort of adolescents and young adults. Moreover, Marzell et al[17] showed an increasing trend of using marijuana among youths living with their parents. A similar conclusion was made in a study on Hispanic youths.[18] Some studies have revealed the pattern of association of using specific substances with sociodemographic characteristics.[16,19-24] Nevertheless, a scope remains open to study the effect of sociodemographic characteristics on polysubstance abuse.

There is evidence of multiple substance abuse among adolescents or young adults, which has a more adverse effect on physical and sexual health.[25] Some studies investigated the pattern of polysubstance abuse in different forms, especially by latent class analysis.[26-30] None of the studies evaluate the likelihood of using one specific substance (say, marijuana) given another one (say, cocaine or methamphetamine).

The purposes of the study include (i) demonstrating the transition of sociodemographic and substance abuse characteristics from 1992 to 2017 among US adolescents and young adults admitted for substance abuse treatment, (ii) evaluating the likelihood of co-occurrence of substances, and (iii) comparing the effect of sociodemographic characteristics on the number of substance abuse for both the years. This study provides importance to adolescents and young adults as they are very susceptible to substances and thus require appropriate policy measures to protect them.

Material and Methods

Study participants and measurements

Since 1992, every year, Treatment Episode Data Set-Admission (TEDS-A) on the patients admitted to any state-licensed or certified substance use treatment centers that receive federal public funding has been collected by the states of the USA to monitor their substance use treatment systems. A standardized format on the selected data consistent with all the states is used to compile the data for the whole country. The TEDS system works as a data repository for treatment data prepared for the Substance Abuse and Mental Health Services Administration (SAMHSA), US Department of Health and Human Services (HHS). This study uses the extracted data of only adolescents and young adults aged less than 25 years who were admitted for treatment in the base year, 1992,[31] and in 2017.[32] The sample of 1992 includes a total of 337,858 adolescents and young adults, which is around 22% of total admissions. The observed number in 2017 is 333 322, which contributes about 17% of the total admissions.

This study concentrates on some selected major substances, including alcohol, marijuana/hashish, cocaine/crack, heroin, other opiates/synthetics, and methamphetamine, to address the objectives. Each respondent reported the primary substances they were ingesting at the time of admission. By comprising the patient's response to all the substances, the key outcome variable, representing the number of substances at the time of admission, is generated.

The characteristics of adolescents and young adults under the study include age at admission, gender, educational qualification, marital status, employment status, living status, race, and ethnicity. All these variables are categorical. The definitions of the variables and their categories are omitted here to avoid repetition, as their distributions in the descriptive analysis part are self-explanatory.

Statistical analysis

Frequency distributions, bar diagrams, and pie charts were used to exhibit descriptive evidence of the study. We used the Cochran-Armitage test to find the significant transition of any sociodemographic characteristics in 2017 from 1992. The likelihood of co-occurrence of substances was measured by the conditional probability of ingesting one substance, given another one. More specifically,

$$P(\text{substance } B|\text{substance } A)=\frac{P(\text{substance } A,\text{substance } B)}{\text{P}(\text{substance } A)}$$

The variable number of reported substances at the time of admission was used as the response variable to find the dynamics of odds ratios (ORs) over the different levels of sociodemographic characteristics. The response variable ranged between 0 and 3 and had ordered features. Thus, the ordered logit regression model[33] can be applied. However, this model requires satisfying the proportional odds assumption. According to this assumption, the coefficient vectors for the set of independent variables for each of the (k-1) binary regressions are identical.[34] Our study used the Brant test[35] to check the proportional odds assumption. In violation of this assumption, the generalized ordered logit model, which does not require the proportional odds assumption, can be applied.[36] As this model is a generalized version of the ordered logit model, the mathematical specification of the model is presented here for better understanding.

$$P(y_i > k \mid X_i) = F(X_i'\beta_k) = \frac{\exp(\alpha_k + X_i'\beta_k)}{1+\exp(\alpha_k + X_i'\beta_k)}, \quad k = 0,1,2,3,$$

where, $y_i > k$ is representing the response indicator, k is the number of reported substances, X_i is the vector of explanatory variables, α_k is the intercept, and β_k is the vector of regression coefficients for the response indicator $y_i > k$.

As the response variable has 4 levels (0-3), the estimated ORs for 3 binary logistic regression models corresponding to the cumulative responses are found for each year. The response groups for the 3 models are defined as (i) $y > 0$ versus $y \leq 0$, i.e., use of no substance versus at least 1 substance, (ii) $y > 1$ versus $y \leq 1$, i.e., use of 1 substance versus at least 2 substances, and (iii) $y > 2$ versus $y \leq 2$, i.e., use of at most 2 substances versus 3 substances. The estimated ORs of each covariate show the dynamics of ORs over the covariate levels. At the same time, the ORs over the cumulative responses assess the change of likelihood for the use of a different combination of substances.

Results

Descriptive Evidence

Admitted adolescents and young adults by sociodemographic characteristics

The distribution of adolescents and young adults by sociodemographic characteristics is presented in Table 1. The Cochran-Armitage test investigates whether there was any significant transition of characteristics in 2017 from 1992. Overall, no evidence of significant change in distribution over 25 years was observed, except for education, living status, and ethnicity. Surprisingly, admissions decreased significantly (about 50%) with 8 or lower years of education ($P = 0.0357$), while the cohorts of 9-11 ($P = 0.063$) and 12 ($P = 0.070$) years experienced an increase. The independent living cohort experienced about a 17% increase in admission ($P = 0.009$). The share of Cuban or other Hispanics was only about 2%, which significantly increased to about 8% in 2017 ($P = 0.027$).

The highest percentage was revealed for the age group 21-24 in both years. However, in 2017, it was around 7% higher than that of 1992 (49%). Shockingly, among the admitted patients, 6.52% belonged to the age cohort 12-14 in 1992, which decreased to 3.85% in 2017. In the other 2 age cohorts, the differences were not substantial. In 1992, around 29% of admitted adolescents and young adults were female. After 25 years, an increase of about 7% in female admission was evident. However, male adolescents and young adults were dominant in both years. The education status indicates that most of the subjects completed their 9-12 years of education, and higher education showed lower admissions.

Admission increased by about 7% for the unemployed in 2017 compared to 1992, while other groups experienced a decrease. No significant differences were evident for homeless and dependent living cohorts. However, as mentioned earlier, the percentage of admissions among the independent living cohort significantly increased (about 17%). The dominant race among the admitted patients was white Americans. However, the transition from 1992 (about 67%) to 2017 (about 63%) was insignificant. Similarly, no significant change was

Table 1. Admitted adolescents and young adults by sociodemographic characteristics

Variables	No. (%)		*P* value
	1992 (N = 337,858)	2017 (N = 333,322)	
Age at the time of admission			
12-14	22,012 (6.52)	12,843 (3.85)	0.1972
15-17	73,005 (21.61)	63,115 (18.94)	0.3193
18-20	76,178 (22.55)	70,343 (21.10)	0.4020
21-24	166,663 (49.33)	187,021 (56.11)	0.1685
Gender			
Female	98,172 (29.06)	121,896 (36.57)	0.1290
Male	238,673 (70.64)	211,110 (63.34)	0.1362
Missing	1013 (0.30)	316 (0.09)	-
Education			
8 or less	54,740 (16.20)	26,323 (7.90)	0.0357
9-11	151,279 (44.78)	114,013 (34.21)	0.0631
12	96,757 (28.64)	128,266 (38.48)	0.0703
13-15	26,929 (7.97)	34,528 (10.36)	0.2790
16 or more	3116 (0.92)	4334 (1.30)	0.3988
Missing	5037 (1.49)	25,858 (7.76)	-
Employment status			
Not in labor force	149,402 (44.22)	128,789 (38.64)	0.2116
Unemployed	79,278 (23.46)	102,716 (30.82)	0.1209
Employed	91,227 (27.00)	75,829 (22.75)	0.2435
Missing	17,951 (5.31)	25,988 (7.80)	-
Living Status			
Homeless	29,830 (8.83)	26,581 (7.97)	0.4132
Dependent living	82,731 (24.49)	103,592 (31.08)	0.1491
Independent living	121,905 (36.08)	175,217 (52.57)	0.0095
Missing	103,392 (30.60)	27,932 (8.38)	-
Race			
White	226,679 (67.09)	211,322 (63.40)	0.2919
Black or African American	65,714 (19.45)	49,765 (14.93)	0.1985
Other races	38,932 (11.52)	64,147 (19.24)	0.0651
Missing	6533 (1.93)	8088 (2.43)	-
Ethnicity			
Mexican	17,541 (5.19)	35,315 (10.59)	0.0783
Puerto Rican	9,908 (2.93)	7,654 (2.30)	0.3901
Cuban or other Hispanic	7,277 (2.15)	27,201 (8.16)	0.0273
Not of Hispanic or Latino Origin	278,585 (82.46)	251,351 (75.41)	0.1108
Missing	24,547 (7.27)	11,801 (3.54)	-

observed for Black or African Americans in 2017 (about 15%) compared to the base year 1992 (about 19%). A majority of ethnic admission was evident for those not of Hispanic or Latino origin, and this group showed no significant transition from about 82% in 1992 to 75% in 2017.

Admitted adolescents and young adults by specific substances

Figure 1 demonstrates the distribution of admitted adolescents and young adults by their reported substance(s). Here, the substance categories are not mutually exclusive, and thus, each subject may belong to multiple categories. This overlapping was also evident from the distribution exhibited in Figure 1. The distribution showed that the maximum reported substance was alcohol in 1992, while it was marijuana or hashish in 2017. The frequency of reported alcohol use in 1992 was 263 566, whereas, in 2017, it was only 109 438 (about 42% of 1992). The number of reported marijuana/hashish increased from 155 392 in 1992 to 192 379 in 2017, increasing about 24%. More than a 60% decrease was evident for cocaine/crack over 25 years. On the other hand, the increase was evident for heroin (267%), followed by other opiates/synthetics (1174%) and methamphetamine (573%).

Admitted adolescents and young adults by the number of substances reported at the time of admission

The distributions of admitted young adults and adolescents by the number of reported substances at the time of admission are exhibited in Figure 2. Both distributions showed that the reported number of substances ranges from 0 to 3. Here, 0 indicated using no substance at the time of admission. Overall, there were no substantial changes in the distributions over the study years. In 1992, only around 5% reported using no substance at the time of admission, and in 2017, it showed about 6%. However, in both study years, an alarming percentage of multiple substance users was evident (23.2% in 1992 and 19.5% in 2017).

Pairwise co-occurrence of substances

The conditional probabilities of using one substance given the other one for the study years are summarized in Figure 3, panels a-f. Figure 3a reveals a substantially higher likelihood for marijuana/hashish given alcohol than other substances. In 1992, the conditional probability was 0.54, while it was 0.61 in 2017. Figure 3b demonstrates that using cocaine/crack increases the likelihood of using other substances, including alcohol, marijuana/hashish, and heroin. The conditional probability of alcohol given cocaine/crack in 1992 was 0.66 compared to 0.29 in 2017. A slight decrease in the conditional probability of marijuana or hashish (0.60 to 0.45) was evident from 1992 to 2017. Although the conditional dependence on heroin given cocaine/crack was negligible in 1992, it was close to the level reported for marijuana in 2017.

The chance of taking alcohol given marijuana or hashish in 1992 (see Figure 3c) was highest (about 82%) among all pairwise co-occurrences, irrespective of the years. It decreased to only 35% in 2017, while significant probabilities for other substances were not apparent in either of the years. A different shape was evident for the conditional dependence of the substances given heroin (see Figure 3d). According to 1992 statistics, heroin influenced using other substances, including alcohol, cocaine/crack, and marijuana/hashish, with probabilities of 0.32, 0.48, and 0.30, respectively. In 2017, it showed the influence of choosing other substances with low probabilities.

Figure 3e shows that given other opiates/synthetics, the highest likelihood was found for alcohol (59%), followed by marijuana/hashish (49%) in 1992. For cocaine/crack, it was around 20%. In 2017, it was observed that 41% used marijuana/hashish, given they had taken other opiates/synthetics. For other substances, the probability fluctuated between 0.11 to 0.24. Finally, Figure 3f reveals the high dependence on alcohol (61%) and marijuana/hashish

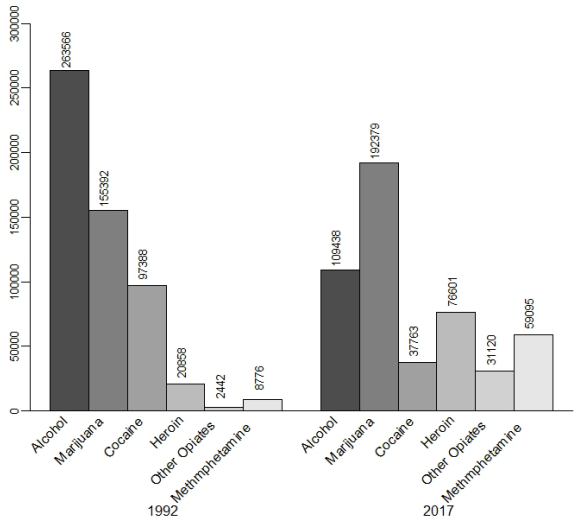

Figure 1. Distribution of admitted adolescents and young adults by their reported primary substance(s)

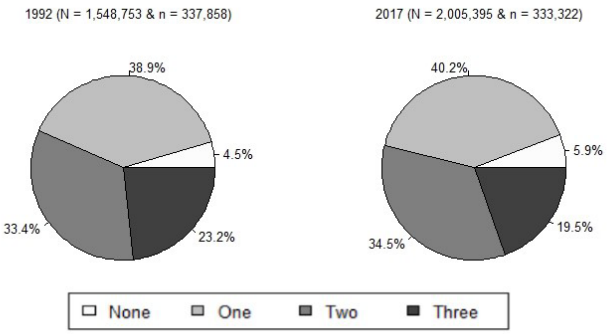

Figure 2. Number of reported substances at the time of admission

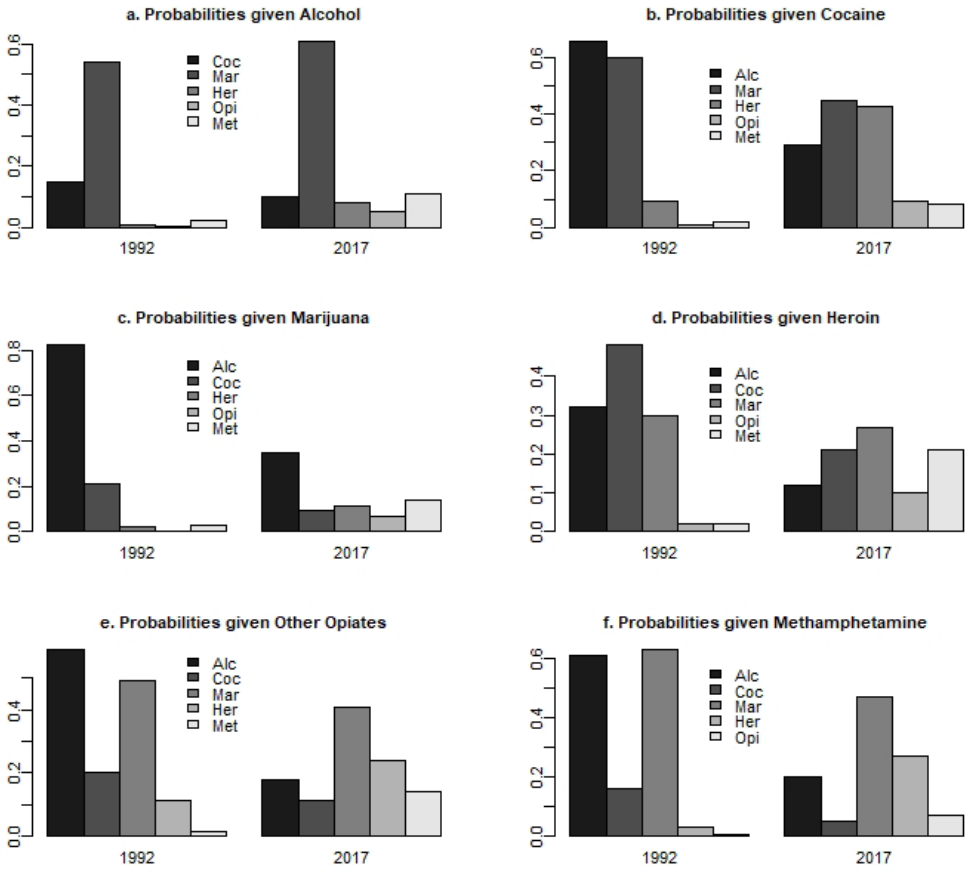

Figure 3. Conditional probabilities of one substance given to others under the study. In the figure, Alc-Alcohol, Mar-Marijuana/Hashish, Coc-Cocaine/Crack, Her-Heroin, Opi-Other Opiates/Synthetics, Met-Methamphetamine

(63%) given methamphetamine in 1992. In 2017, 47% of methamphetamine users also used marijuana/hashish, while it varied from 7% to 27% for other substances.

Statistical modeling

Ordered logit model

The ordered logit models of the number of reported substances at the time of admission on the characteristics, including age, gender, education, employment status, living status, race, and ethnicity, are fitted for 1992 and 2017 separately. The Brant tests for overall models of both years showed a significant violation of the proportional odds assumption with P values < 0.001. This test also allowed us to check which characteristics violated this assumption. The corresponding P values indicate that every characteristic violated the assumption except only for a level of employment in 1992. Due to the violation of the key assumption of the model, the estimated ordered logit model was not explicitly presented in this study. The fitted models and the detailed Brant test results are presented in Tables S1 and S2 in the supplementary materials.

Generalized ordered logit model

The estimated generalized ordered logistic regression models for 1992 and 2017 are presented in Table 2. It is observed that the odds in favor of the age cohorts 15-17, 18-20, and 21-24 were consistently higher for all cumulative responses against the reference age cohort 12-14. A similar pattern was evident in both the study years except substantially higher ORs for the last 2 age levels in 1992. The worst indicator was apparent from the third model in both years. The ORs indicated a significantly and monotonically higher likelihood of using 3 substances than, at most, 2 substances with the increase in age. By gender, the male group showed 66% and 6% higher odds than females in favor of at least 1 substance and 2 substances, respectively, in 1992, whereas 8% lower odds for them in favor of 3 substances was evident. In 2017, 41% higher odds were evident for males than their counterparts in favor of at least 1 substance, whereas males and females were not significantly different for more than one substance.

Compared to the reference education of 8 years or less, higher odds in favor of at least 1 substance were found for the categories 9-11 and 12 years of education in 1992. In contrast, lower odds were observed for higher education categories such as 13-15 and 16 and more, but these were not statistically significant. For the 2017 model, all categories showed significantly more association

Table 2. Generalized Ordered Logistic Regression

	1992: OR (SE)			2017: OR (SE)		
	Model 1: y > 0	**Model 2: y > 1**	**Model 3: y > 2**	**Model 4: y > 0**	**Model 5: y > 1**	**Model 6: y > 2**
Age at the time of admission (Ref: 12-14 years)						
15-17	3.14 (0.14)***	1.96 (0.05)***	1.90 (0.06)***	3.56 (0.24)***	1.68 (0.04)***	1.91 (0.08)***
18-20	7.20 (0.44)***	2.32 (0.06)***	2.45 (0.08)***	3.94 (0.30)***	2.69 (0.07)***	2.84 (0.12)***
21-24	13.47 (0.82)***	2.55 (0.06)***	2.79 (0.09)***	5.48 (0.41)***	3.09 (0.08)***	3.00 (0.13)***
Gender (Ref: Female)						
Male	1.66 (0.05)***	1.06 (0.01)***	0.92 (0.01)***	1.41 (0.04)***	0.99 (0.01)	1.01 (0.01)
Education (Ref: 8 or less)						
9-11	1.40 (0.06)***	0.97 (0.02)*	0.92 (0.02)***	1.50 (0.08)***	1.03 (0.02)*	0.94 (0.02)***
12	1.19 (0.07)***	0.78 (0.01)***	0.80 (0.02)***	1.38 (0.08)***	0.94 (0.02)***	0.92 (0.02)***
13-15	0.95 (0.07)	0.59 (0.01)***	0.66 (0.02)***	1.51 (0.11)***	1.01 (0.02)	1.00 (0.02)
16 or more	0.79 (0.15)	0.37 (0.02)***	0.42 (0.03)***	1.56 (0.22)***	0.74 (0.03)***	0.75 (0.03)***
Employment status (Ref: Not in labor force)						
Unemployed	1.01 (0.04)	1.02 (0.01)*	1.03 (0.01)**	0.75 (0.03)***	0.96 (0.01)***	1.06 (0.01)***
Employed	1.01 (0.05)	0.59 (0.01)	0.62 (0.01)***	0.61 (0.03)***	0.70 (0.01)***	0.70 (0.01)***
Living Status (Ref: Homeless)						
Dependent living	0.56 (0.03)***	0.56 (0.01)***	0.81 (0.01)***	0.38 (0.04)***	0.78 (0.01)***	0.99 (0.02)
Independent living	0.43 (0.02)***	0.49 (0.01)***	0.65 (0.01)***	0.29 (0.03)***	0.62 (0.01)***	0.98 (0.02)
Race (Ref: White)						
Black or African American	0.53 (0.02)***	1.10 (0.01)***	0.80 (0.01)***	0.53 (0.02)***	0.40 (0.00)***	0.36 (0.01)***
Other races	1.47 (0.12)***	0.95 (0.02)**	0.89 (0.02)***	0.98 (0.05)	0.89 (0.01)***	0.73 (0.01)***
Ethnicity (Ref: Mexican)						
Puerto Rican	1.05 (0.20)	1.71 (0.06)***	1.56 (0.06)***	0.20 (0.03)***	1.01 (0.03)	4.09 (0.16)***
Cuban or other Hispanic	0.66 (0.12)**	1.21 (0.05***	1.26 (0.06)***	0.24 (0.03)***	1.02 (0.02)	3.58 (0.11)***
Not of Hispanic or Latino Origin	0.53 (0.08)***	1.31 (0.04)***	1.32 (0.05)***	0.22 (0.02)***	1.23 (0.02)***	4.47 (0.12)***
Constant	17.47 (2.68)***	1.10 (0.04)**	0.20 (0.01)***	143.88 (20.56)***	0.84 (0.03)***	0.03 (0.00)***

Note: *** *P* value < 0.01, ** *P* value < 0.05, * *P* value < 0.10.

with at least 1 substance. Except for 1 level of education in 2017, 4 other models (Models 2, 3, 5, and 6) showed less association to at least 2 or 3 substances with the increase in education. Employment status showed that the employed group was significantly better off than the reference group, not in the labor force. From models of 1992, slightly higher likelihoods were evident for the unemployed in comparison to the reference. A similar likelihood was revealed for the third model in 2017, while the other 2 models showed the opposite scenario.

All models of 1992 and the first 2 models of 2017 unveiled significantly lower odds for those with dependent living arrangements than the homeless. The scenario for those with independent living arrangements was much better than for those with dependent living status. White adolescents and young adults showed a higher likelihood in most combinations of polysubstance than black or African Americans. Mexicans were significantly more likely to take at least 1 substance than other ethnic communities. In contrast, significantly lower likelihoods were evident for at least 2 or 3 substances. The worst picture was evident from Model 6 in 2017. Compared to Mexicans, Puerto Ricans were about 4 times more likely to use 3 substances than at most 2 substances, followed by Cuban or other Hispanics (3.58 times) and not Hispanic or Latino origin (4.47 times).

Discussion

This study compared adolescents and young adults admitted for substance abuse treatment in 1992 and 2017 to examine the transition of sociodemographic and substance abuse characteristics, evaluate the likelihood of co-occurrence of substances, and identify significant sociodemographic factors associated with polysubstance abuse. Overall, both years experienced significant admissions for adolescents and young adults. A significant transition in 2017 compared to 1992 was evident in education, living status, and ethnicity. Substance-specific transition showed alcohol was dominant in 1992 and decreased in 2017, while marijuana/hashish increased to hold the highest admissions in 2017. Also, heroin, other opiates/synthetics, and methamphetamine as primary substances experienced an increase, while cocaine/crack showed a decrease. The pairwise co-occurrences exhibited

a considerable variation in the likelihood of using one substance given another one. The ORs obtained from generalized ordered logit models showed significantly higher odds of one or more substances with age, while education showed the opposite scenario. A mixed effect of gender was evident in 1992, whereas females were significantly less likely with one or more substances than males in 2017. Other significant vulnerable groups were those not in the labor force, homeless, white, and Mexican Americans.

Although female admissions increased over 25 years, the male group remained dominant in both years. Despite limited research for the cohort under the study, the literature also suggests significant gender differences in the diagnosis, presentation, types of illness, and treatment[37]. With education, substantial changes in the distribution of admissions were evident, especially a decrease for the 8th graders and an increase for 9-11 years and the 12 graders. The annual study "Monitoring the Future" showed a similar pattern of transition of prevalence for the 8th and 12th graders from 1991 to 1998[38].

This study demonstrated a significant increase in admission for adolescents and young adults with independent living status from 1992 to 2017. Although a similar cohort comparison is not available in the literature, Martin et al[39] also showed an increasing trend in admissions among the non-homeless, including dependent and independent living arrangements and pregnant women who used opioids during their pregnancy. However, no substantial change for non-homeless older adults in admissions was evident based on 2000 to 2012 TEDS-A data.[40] This study also showed the ethnic dominance in admissions among non-Hispanic or non-Latino groups, which is consistent with patterns based on different other cohorts of people.[16,21,39]

Substance-specific transition showed increased admissions for marijuana/hashish, heroin, other opiates/synthetics, and methamphetamine and a decrease for alcohol and cocaine/crack. The directions of transitions of our sample are similar to those shown by Mazumder et al[16] based on admissions of all ages. Polysubstance use is a major public health concern and is significantly associated with several adverse health outcomes,[41] especially for adolescents, including physical development and mental health problems.[42,43] This study showed a substantial percentage of polysubstance use among admitted adolescents and young adults. Several other studies also demonstrated evidence of polysubstance use by adolescents and young adults.[26-29,44]

Many studies examined the co-occurrence of substances with health outcomes, especially mental health[45,46]; some examined the co-occurrence with nicotine or tobacco products and other substances[47,48]; some studied the co-occurrence pattern, especially by latent class analysis, cluster analysis,[44] a recent study by market basket[49]; however, no one has shown pairwise co-occurrences by using the conditional probability concept. To our knowledge, this is the first study to evaluate the likelihood of pairwise co-occurrences using the conditional probability approach. This approach is simple and has better interpretability in finding the most commonly co-occurring substances.

The response variable having more than 2 categories with an ordered relationship is generally modeled by the ordered logistic regression model.[33] However, this model requires to satisfy an assumption, commonly known as proportional odds assumption,[34] which is violated very often in real-life scenarios.[36] This study demonstrated that the ordered logit model failed to satisfy the assumption in dealing with the ordered response variable, the number of reported substances. To overcome this, we used a generalized ordered logit model that is free from proportional odds assumption.[36] This model helped to show the dynamics of ORs for the levels of the characteristics of adolescents and young adults. Several efforts have been made to evaluate the significant variation of sociodemographic characteristics based on individual substances or a group of substances versus no substance for the different cohorts of people.[16,19,21-24] However, the sociodemographic association with incremental use of substances versus their counterpart is not available in the literature. In this context, this study contributes to the literature, especially on modeling ordered response in substance abuse research. It also helps to investigate the effects of the factors on the combination of substance use.

This study has several strengths. Firstly, it used all US adolescents and young adults admitted to any state-licensed or certified substance use treatment centers that received federal public funding in 1992 and 2017. Both years had a substantially large sample (337 858 in 1992 and 333 322 in 2017). Secondly, this is the first study that demonstrated the transition of sociodemographic and substance abuse characteristics for this cohort of population and evaluated the likelihood of co-occurrences of substances using the conditional probability approach. Thirdly, the application of generalized ordered logistic regression provided an additional opportunity to identify factors associated with the incremental use of polysubstance. Despite having all these strengths, the study had several limitations. Many states collected data that included multiple admissions for the same patient, and thus, the data represent admissions, not the patients. Therefore, considering the number of admissions as the number of patients might be overestimated. Another limitation was that data collection was limited to primary, secondary, and tertiary substances reported at the time of admission. It did not necessarily represent a complete list of all substances used at the time of admission.

Conclusion

This is the first study that used US adolescents and young adults admitted to any state-licensed or certified substance use treatment centers to demonstrate the changes in the sociodemographic and substance abuse patterns over the period, evaluate the likelihood of pairwise co-occurrence of substances, and the significant factors associated with the risk of using substances incrementally. The findings may help to understand the overall changes in the scenario from 1992 to 2017 and take necessary measures by the stakeholders to reduce the burden of this public health problem.

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Authors' Contribution

Conceptualization: Md Tareq Ferdous Khan, Shrabanti Mazumder.
Data curation: Md Habibur Rahman, Most Alina Afroz, Humayun Kiser.
Formal analysis: Shrabanti Mazumder, Md Habibur Rahman, Humayun Kiser, Mohammad Alfrad Nobel Bhuiyan.
Methodology: Md Tareq Ferdous Khan, Shrabanti Mazumder.
Project administration: Md Tareq Ferdous Khan, Shrabanti Mazumder.
Supervision: Md Tareq Ferdous Khan.
Writing–original draft: Md Tareq Ferdous Khan, Shrabanti Mazumder, Md Habibur Rahman, Most Alina Afroz, Humayun Kiser, Mohammad Alfrad Nobel Bhuiyan.
Writing–review & editing: Md Tareq Ferdous Khan, Shrabanti Mazumder, Mohammad Alfrad Nobel Bhuiyan.

Competing Interests

The authors report no conflict of interest.

Data Availability Statement

The datasets extracted and/or analyzed during the current study are available on the site https://www.datafiles.samhsa.gov/study-series/treatment-episode-data-set-admissions-teds-nid13518.

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Supplementary Files

Supplementary file 1 contains Table S1 and Table S2.

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