

Substance use and exercise participation among young adults: parallel trajectories in a national cohort-sequential study

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ABSTRACT

Aims This study examined the extent to which the trajectory of participation in sports, athletics or exercising (PSAE) covaried with substance use in early adulthood controlling for team sports participation using parallel process latent growth curve modeling. **Design, setting and participants** Analysis of data collected from a series of panel studies using a cohort-sequential design. Specifically, the analyses used longitudinal data from 11 741 individuals from the graduating classes of 1986–2001, first surveyed as seniors in American high schools. Up to four additional follow-up surveys were administered to age 26 years. Data were collected using in-school and mailed self-administered questionnaires. **Measurements** Level of PSAE, past-30-day alcohol, cigarette and marijuana use frequency and any past-30-day use of illicit drugs other than marijuana (IOTM) were the main processes of interest. Self-reported race/ethnicity, college status at age 19/20 years, parental education, gender and team sports participation during high school were included as covariates. **Findings** Results indicate that higher initial levels of PSAE related to lower initial substance use prevalence rates other than alcohol, and lower initial prevalence rates of substance use then corresponded with lower substance use rates throughout early adulthood. Further, as individuals increased PSAE levels throughout early adulthood, the frequency of their use of cigarettes, marijuana and IOTM correspondingly decreased. **Conclusions** Increased participation in sports, athletics or exercising (PSAE) is related to significantly lower substance use frequency at modal age 18 and through significantly and negatively correlated growth trajectories through early adulthood. Encouraging PSAE among adolescents and early adults may relate to lower substance use levels throughout early adulthood.

Keywords Alcohol, cigarettes, exercise, illicit drugs, marijuana, parallel process latent growth curve modeling, parallel trajectory modeling, substance use, team sports participation, young adult.

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INTRODUCTION

Use of physical activity in substance abuse prevention has been highlighted by the US National Institute on Drug Abuse (NIDA) [1] and the National Institutes of Health [2,3]. Theory, neurobiology and other research support a preventive and treatment effect of exercise on substance use [4–14]. However, NIDA has identified important knowledge gaps in this relationship, including physical activity type, context, persistence and variation across the life-span [15]. Individuals aged 18–25 years are more likely than youth or older adults to use alcohol, tobacco or illicit drugs [16]. Early adulthood transitions significantly affect a broad range of health outcomes

[17], including substance use [18,19]. If physical activity relates significantly to young adult substance use, such information may strengthen prevention, reduction and treatment efforts.

Young adult physical activity and substance use research has focused primarily on sports participation. Cross-sectional studies have found that sports participation—particularly team-based competitive sport participation—relates to increased alcohol use but lower cigarette and illegal drug use [20,21]. Research examining non-sport-related exercise and substance use is less available. One cross-sectional study with US adults in 24 states found that past-month leisure activity related to lower cigarette use and higher alcohol

use [22]. Longitudinal studies including young adults also have focused on sports participation and generally have found positive relationships with alcohol use [23–26] and negative relationships with illicit drug or tobacco use [23,25]. Longitudinal research examining how general exercise relates to young adult substance use is unavailable.

Hypotheses related to team sports participation and substance use include both protective and risk-related factors [27]. If substance use varies significantly with physical activity, and if such variation is affected by exercise type, such information may strengthen substance abuse prevention and treatment efforts and identify at-risk populations. This study aims to assess the effect of exercise on substance use that is not due to sports participation by examining the covariation of early adulthood trajectories of participation in sports, athletics or exercising (PSAE) and past 30-day substance use from modal ages 18 to 25/26, controlling for high school team sports participation.

METHODS

Sample

The study utilizes data from the NIDA-sponsored Monitoring the Future (MTF) study [28]. Briefly, a nationally representative sample of approximately 15 000 high school seniors from about 130 schools is selected yearly. Self-administered classroom surveys are completed by students during a normal class period. A representative random subsample of 2400 seniors is selected from each cohort for longitudinal follow-up; substance users are over-sampled (analyses include weighting to account for sampling procedures). Respondents are divided randomly, with half surveyed in even-numbered years and half in odd-numbered years. Follow-up questionnaires are mailed in the spring, with a modest monetary incentive. Overall response rates for the first follow-up (1–2 years past high school) average 56%; rates for the second to sixth follow-ups average 52% [28]. In order to reduce respondent burden but still obtain a wide variety of measures, MTF uses six different questionnaire forms; items on exercise participation are included on two forms. The current sample was limited to class cohorts from 1986 onwards, when team sports participation was first measured, to individuals responding to the relevant questionnaire forms, and to cohorts with the potential to have participated in four follow-up surveys. Thus, analyses included individuals first surveyed as high school seniors from 1986–2001, with modal ages ranging from 18 (high school seniors) to 25/26 (completing follow-up four).

Measures

Past 30-day substance use

Alcohol and marijuana use frequency were measured as 1 = no occasions, 2 = one to two, 3 = three to five, 4 = six to nine, 5 = 10–19, 6 = 20–39, 7 = 40+ occasions. Smoking frequency was measured as 1 = not at all, 2 = less than one cigarette per day, 3 = one to five cigarettes per day, 4 = about 1/2 pack per day, 5 = about one pack per day, 6 = about one-and-a-half packs per day, 7 = two packs or more per day. Any use of illicit drugs other than marijuana (IOTM) was a dichotomy indicating any use of one or more of: LSD, other hallucinogens, cocaine, heroin, other narcotics, amphetamines, barbiturates or tranquilizers (because of the low use frequency for illicit drugs other than marijuana among this sample, a dichotomous use status measure was considered more appropriate than a mean use frequency measure).

Exercise participation

PSAE was measured by asking: 'How often do you actively participate in sports, athletics or exercising' (1 = never, 2 = a few times a year, 3 = once or twice a month, 4 = at least once a week, 5 = almost every day).

Control variables

Due to the complexity of the analytical models employed, a limited number of control measures were possible. Selected measures were chosen that (i) were clearly exogenous with respect to substance use and (ii) have been shown to relate significantly to both exercise participation and substance use [28–33]. Gender, race/ethnicity, parental education and school athletic team participation were used as time-invariant controls measured at modal age 18 years. Self-identified race/ethnicity was coded as white (1) versus non-white (0). Parental education (a proxy for family-of-origin socio-economic status) was a five-point scale assessing educational attainment for father and mother. Team sports participation was measured by asking: 'To what extent have you participated in athletic teams during this school year?' (1 = not at all, 2 = slight, 3 = moderate, 4 = considerable, 5 = great). College status was measured at first follow-up (age 19/20) and indicated being a full-time student either attending or with plans to graduate from a 4-year program.

Analysis

Parallel process latent growth curve modeling was conducted using Mplus 6.1 [34]. Mplus utilizes full-information maximum likelihood estimation, and thus uses all available data [35,36]. Outcomes can include

missing data and are modeled conditional on covariates; missing data on covariates are addressed by including covariates in the model (via modeling covariate means, thresholds or variances [37,38]). Piecewise models work particularly well for modeling longitudinal substance use [39,40], and were indicated for all processes. Two distinct time-periods were identified: ages 18–21/22 (senior year to second follow-up) and ages 21/22–25/26 (second to fourth follow-up). Thus, three latent variables were used to model each process: an intercept, a linear slope for ages 18–21/22 and a linear slope for ages 21/22–25/26. The intercept denotes initial status at age 18; slopes denote growth rates [41].

Only one substance use outcome was modeled simultaneously with PSAE. Correlations between the respective latent factors for each process were modeled as well as direct effects of initial status on growth rate factors of the opposing process. All models used maximum likelihood estimation with robust standard errors. Alcohol, cigarette and marijuana use were treated as normally distributed interval measures. While this assumption is clearly not valid, it is perhaps not unreasonable given the large sample size; moreover, care was taken to ensure that

discussion of significance was limited to findings with $P \leq 0.01$. For IOTM, the logistic model for categorical outcomes with a numerical integration algorithm was used [42]. Coefficients for processes other than IOTM are expressed as standardized linear regression estimates; IOTM results are expressed as standardized logits.

Figure 1 illustrates the final full multivariate model structure using past 30-day cigarette smoking. Model fit for the final alcohol/PSAE model improved significantly with the addition of a direct path from parental education to the first alcohol frequency slope. The final IOTM/PSAE model included the following specifications: team sports participation mean and variance were fixed (2.603 and 0.917, respectively) based on results from other multivariate models; the direct path between the PSAE intercept and second IOTM slope was removed. Further, IOTM models would not converge with inclusion of all five covariates; thus, two versions of the final model were run: one excluding team sports (but including the remaining four covariates) and one excluding parental education (but including the remaining four covariates). Excluding parental education was based on the multivariate model excluding team sports, where no significant direct path

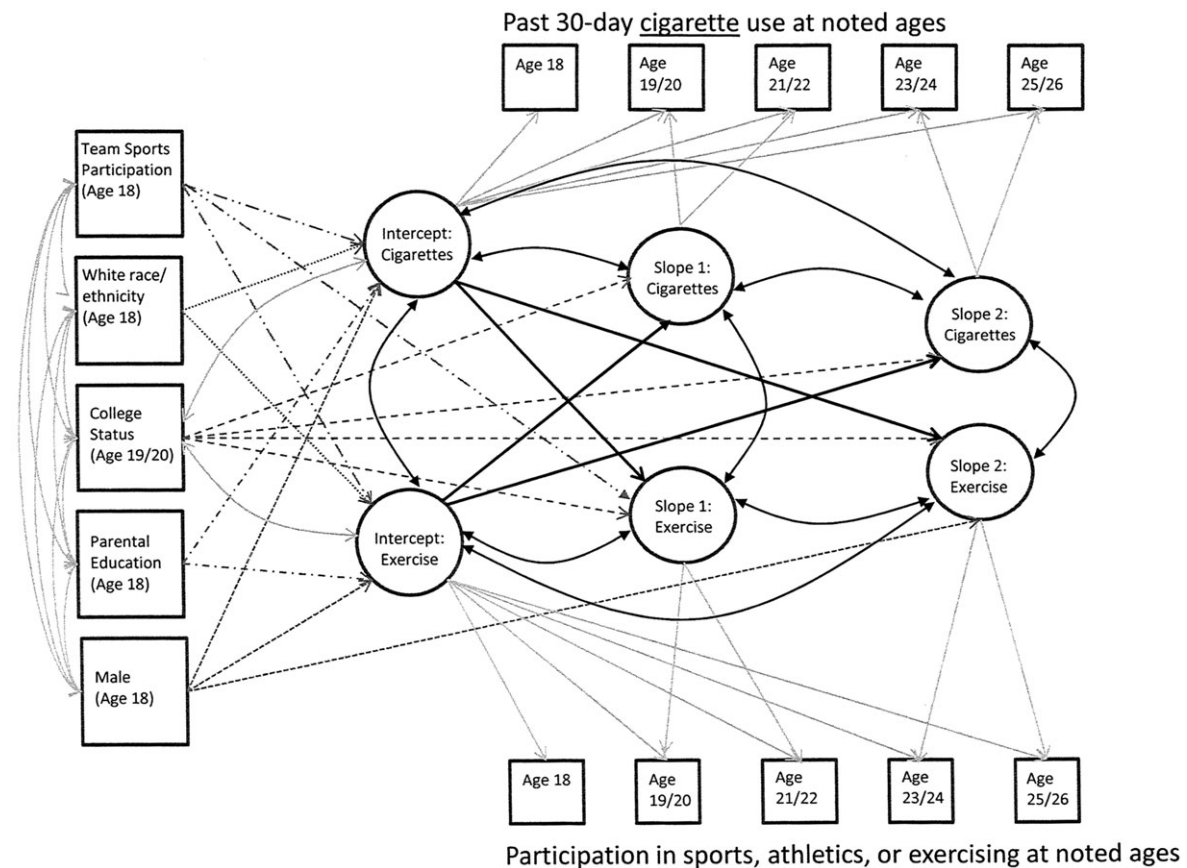


Figure 1 Full piecewise parallel process latent growth curve model using cigarette use as an example

Table 1 Sample statistics (total sample $n = 11\,741$).

	Range	Mean (standard deviation) at age:				
		18	19/20	21/22	23/24	25/26
Main processes to model						
Participation in sports, athletics or exercising	1–5	3.87 (1.29)	3.71 (1.21)	3.64 (1.21)	3.60 (1.20)	3.58 (1.21)
Past 30-day alcohol use	1–7	2.21 (1.48)	2.41 (1.52)	2.71 (1.58)	2.67 (1.52)	2.64 (1.51)
Past 30-day cigarette use	1–7	1.69 (1.22)	1.72 (1.30)	1.75 (1.33)	1.73 (1.33)	1.68 (1.32)
Past 30-day marijuana use	1–7	1.50 (1.28)	1.45 (1.22)	1.45 (1.23)	1.39 (1.20)	1.36 (1.16)
Any past 30-day use of illicit other than marijuana	0,1	0.09 (0.29)	0.07 (0.25)	0.06 (0.25)	0.06 (0.24)	0.06 (0.23)
Control variables (measured at age 18)						
Male	0,1	0.48 (0.50)				
White race/ethnicity	0,1	0.72 (0.45)				
Average parental education	1–5	3.03 (1.17)				
Participation in school athletic teams	1–5	2.61 (1.72)				
Control variables (measured at age 19/20)						
Full-time student at 4-year college	0,1		0.45 (0.50)			

was found between parental education and the IOTM intercept.

RESULTS

Analytical sample

From the 16 class cohorts from 1986 to 2001, a total of 12 289 individuals responded to the applicable questionnaire forms. Of these, 548 (4%) were removed due to not having valid data for at least one observation for each outcome or for having implausible PSAE and team sports data. Removed individuals were significantly more likely to be male and report low average parental education; removed individuals were significantly less likely to be full-time college students at first follow-up. The final analytical sample included 40 424 observations from 11 741 individuals. Retention rates were: 69% follow-up 1, 63% follow-up 2, 58% follow-up 3, 54% follow-up 4.

Sample descriptives and unconditional growth models

Table 1 provides sample statistics and Fig. 2 shows normative trajectories of the processes. Mean alcohol use frequency increased from age 18 to 21/22 (from 2.21 to 2.71) followed by a minimal decrease to age 25/26. For cigarette use, an increase from age 18 to 21/22 was observed (from 1.69 to 1.75), followed by a slight decrease to 1.68 by age 25/26. Marijuana use showed the flattest trajectory over time, decreasing slightly from 1.50 at age 18 to 1.45 at age 21/22, and then to 1.36 by age 25/26. IOTM prevalence dropped from 9.4% at age 18 to 6.4% at age 21/22, and then to 5.6% by age 25/26. PSAE decreased somewhat from 3.87 at age 18 to 3.64 at age 21/22; the decrease then flattened to age 25/26

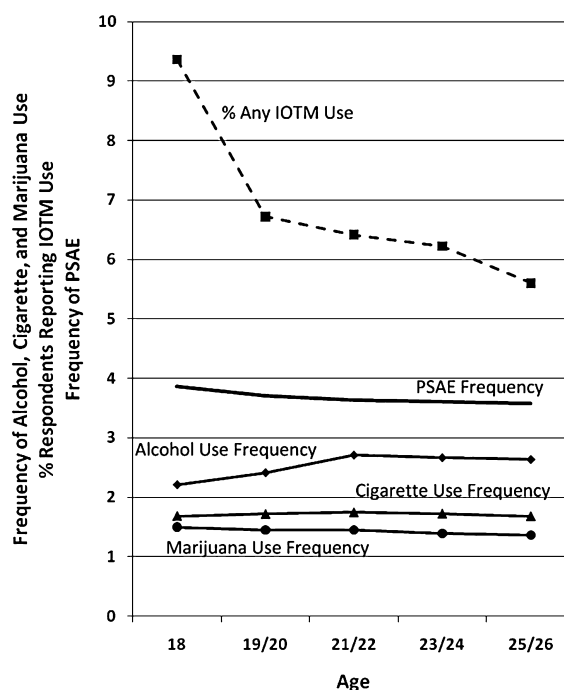


Figure 2 Normative trajectories of past 30-day substance use frequency and active participation in sports, athletics or exercising (PSAE); $n = 11\,741$. IOTM: dichotomous indicator for illicit drugs other than marijuana; includes lysergic acid diethylamide (LSD), other hallucinogens, cocaine, heroin, other narcotics, amphetamines, barbiturates and tranquilizers. PSAE measured on five-point scale of 1 = never, 2 = a few times a year, 3 = once or twice a month, 4 = at least once a week, 5 = almost every day. Past 30-day alcohol and marijuana use measured on a seven-point scale of 1 = 0 occasions, 2 = 1–2, 3 = 3–5, 4 = 6–9, 5 = 10–19, 6 = 20–39, 7 = 40 or more occasions. Past 30-day cigarette use measured on a seven-point scale of 1 = not at all, 2 = less than one per day, 3 = one to five per day, 4 = about $\frac{1}{2}$ pack per day, 5 = about one pack per day, 6 = about one-and-a-half packs per day, 7 = 2+ packs per day

Table 2 Overall model fit and growth trajectory for the unconditional growth models.

<i>Model fit indicators</i>						
<i>Variable</i>	χ^2 (<i>d.f.</i>)	<i>CFI</i>	<i>TLI</i>	<i>RMSEA</i>		
PSAE ^a	17.695 (6)	0.998	0.997	0.013		
Alcohol use	12.614 (6)	0.999	0.998	0.010		
Cigarette use	24.670 (6)	0.997	0.995	0.016		
Marijuana use	7.103 (6)	1.000	0.999	0.004		
IOTM ^b use	30.714 (22)	–	–	–		
<i>Parameter estimates</i>						
<i>Means</i>						
	<i>I</i>	<i>(P)</i>	<i>S1</i>	<i>(P)</i>	<i>S2</i>	<i>(P)</i>
PSAE	3.860	(0.000)	–0.121	(0.000)	–0.022	(0.007)
Alcohol use	2.196	(0.000)	0.268	(0.000)	–0.038	(0.000)
Cigarette use	1.688	(0.000)	0.066	(0.000)	–0.028	(0.000)
Marijuana use	1.498	(0.000)	0.003	(0.635)	–0.046	(0.000)
IOTM use	0 ^c		–0.299	(0.021)	–0.415	(0.011)
<i>Correlations</i>						
	<i>I,S1</i>	<i>(P)</i>	<i>I,S2</i>	<i>(P)</i>	<i>S1,S2</i>	<i>(P)</i>
PSAE	–0.450	(0.000)	–0.210	(0.000)	–0.101	(0.152)
Alcohol use	–0.344	(0.000)	–0.189	(0.000)	–0.221	(0.000)
Cigarette use	–0.191	(0.000)	–0.134	(0.000)	–0.200	(0.000)
Marijuana use	–0.431	(0.000)	–0.210	(0.000)	–0.139	(0.012)
IOTM use	–0.321	(0.005)	–0.105	(0.429)	0.245	(0.243)

n = 11 741. Mean and slope values are unstandardized. Correlations reported using standardized estimates (for IOTM, the estimated change in the logit). χ^2 (*d.f.*): chi-square value (degrees of freedom); CFI: comparative fit index; TLI: Tucker–Lewis coefficient; RMSEA: root mean square error of approximation; I: intercept, S1: slope 1 (ages 18–21/22); S2: slope 2 (ages 21/22–25/26). ^aParticipation in sports, athletics or exercising. ^bIOTM: dichotomous indicator for illicit drugs other than marijuana; includes lysergic acid diethylamide (LSD), other hallucinogens, cocaine, heroin, other narcotics, amphetamines, barbiturates and tranquilizers. Reported χ^2 test of model fit is for binary and ordered categorical (ordinal) outcomes. Most model fit indices are unavailable for binary processes. ^cMplus fixes the mean of intercept growth factors for categorical variables at zero.

(3.58). Mean participation in school athletic teams at age 18 was 2.61. The Pearson correlation between PSAE and school athletic team participation at age 18 was 0.57 (*P* < 0.001). Thus, while overlapping, the two terms each retain a unique measure of an individual’s exercise participation.

Table 2 presents unconditional univariate growth model results. Close-fit indices suggested an acceptable fit for all processes [43,44]. The final rows report correlations between intercepts and slopes indicating how fast changes in PSAE or substance use occurred based on initial status at age 18. Negative correlations indicate that individuals with lower initial status grew fastest over time (positive slopes) or declined more slowly (negative slopes) [40]. Thus, the negative correlations between the PSAE intercept and both slopes (–0.450, –0.210) indicate that high school seniors with higher levels of exercising experienced the fastest declines in exercising; however, such individuals continued to have highest

mean exercising levels to age 25/26. A similar relationship was observed for IOTM, where the significant negative correlation between the intercept and first slope (–0.321) indicated that seniors with higher IOTM use experienced the fastest declines in use to age 21/22. Negative correlations between alcohol, cigarette and marijuana use frequency intercepts and growth rates to age 21/22 (–0.344, –0.191, –0.431, respectively) indicate that youth with lower use of these substances at age 18 experienced faster increases in use than did youth with higher initial use. In contrast, the negative correlations between alcohol, cigarette and marijuana use frequency intercepts and growth rates from ages 21/22 to 25/26 (–0.189, –0.134, –0.210) show that youth with the lowest rates of use at age 18 showed the slowest declines in use during these years. For all three substances, further examination of the data showed that while youth with lower initial use frequency did experience an increase in use to age 21/22, their mean use

continued to remain lower than youth with higher initial use to age 25/26. In contrast, youth with high initial status use showed a regression towards the mean in use frequency, yet continued to show higher mean use over time. No significant correlation was observed between the IOTM intercept and second slope, indicating that any IOTM use at age 18 did not relate significantly to the rate of change in IOTM prevalence from age 21/22 to age 25/26. Similar to the other substances examined, not using IOTM at age 18 was related to lower use to age 25/26.

Bivariate and multivariate growth models

Results from bivariate parallel process growth models (without control variables) are shown in Table 3. Full multivariate models were built in a staged fashion, with final model results shown in Table 4. The discussion below focuses primarily on the main parameters of interest—between-process correlations—with additional discussion of the direct path results for team sports on substance use intercepts. Between-process correlations answer two key questions: (i) did PSAE and substance use covary at age 18; and (ii) did the rate of change in PSAE covary with the rate of change of substance use over time? Controlling for the direct path results for team sports investigates if athletic team participation substantively affected the observed relationships.

Past 30-day alcohol use frequency and PSAE

Bivariate models showed that higher PSAE was associated with higher age 18 alcohol use frequency (correlation $SU\ I \leftrightarrow EX\ I$, $r = 0.094$, $P < 0.001$). This relationship

remained substantively unchanged in models adding each of the five control variables separately. When including two control measures simultaneously, the correlation became insignificant in two models (data not shown): (i) inclusion of both race/ethnicity and team sports participation ($SU\ I \leftrightarrow EX\ I$, $r = 0.017$, $P = 0.258$) and (ii) inclusion of both gender and team sports participation ($SU\ I \leftrightarrow EX\ I$, $r = -0.004$, $P = 0.806$). The final multivariate model showed the correlation as negative but non-significant ($SU\ I \leftrightarrow EX\ I$, $r = -0.015$, $P = 0.322$). Final model estimates showed that team sports participation did have a significant and positive relationship with alcohol use at age 18 ($\rightarrow SU\ I = 0.036$, $P = 0.001$), in contrast with all other substances where the relationship was significant and negative.

The rate of change in PSAE from ages 18 to 21/22 did not covary significantly with alcohol use frequency change. However, a significant and positive correlation was observed from ages 21/22 to 25/26; during this time, both processes were flattening (multivariate model $SU\ S2 \leftrightarrow EX\ S2$, $r = 0.108$, $P = 0.002$).

Past 30-day cigarette use frequency and PSAE

In bivariate and multivariate models, higher PSAE was associated with lower age 18 cigarette use frequency (multivariate model $SU\ I \leftrightarrow EX\ I$, $r = -0.135$, $P < 0.001$). Increases in PSAE were related to significant decreases in cigarette use from ages 18 to 21/22 (multivariate model $SU\ S1 \leftrightarrow EX\ S1$, $r = -0.139$, $P < 0.001$). PSAE increases from ages 21/22 to 25/26 were also related to decreases in cigarette use (multivariate model $SU\ S2 \leftrightarrow EX\ S2$, $r = -0.128$, $P < 0.001$).

Table 3 Results from bivariate parallel process growth models for participation in sports, athletics, or exercising (PSAE) and past 30-day substance use.

	Alcohol	(P)	Cigarettes	(P)	Marijuana	(P)	IOTM ^a	(P)
Between-process correlations (<i>r</i>)								
SU I ↔ EX I	0.094	(0.000)	-0.175	(0.000)	-0.071	(0.000)	-0.080	(0.000)
SU S1 ↔ EX S1	0.020	(0.314)	-0.197	(0.000)	-0.027	(0.113)	-0.114	(0.029)
SU S2 ↔ EX S2	0.093	(0.006)	-0.145	(0.000)	-0.023	(0.347)	-0.049	(0.618)
Model fit statistics								
Model N	11 741		11 741		11 741		11 741	
χ ² (d.f.)	57.732 (30)		78.562 (30)		41.819 (30)		–	
CFI, TLI	0.998, 0.997		0.997, 0.996		0.999, 0.999		–	
RMSEA	0.009		0.012		0.006		–	

Standardized values shown for correlations. For alcohol, cigarettes and marijuana, the coefficients are expressed as traditional linear regression estimates. For IOTM, the logistic model for categorical outcomes with a numerical integration algorithm was used; thus, estimates use logits. SU I: substance use intercept; SU S: substance use slope; EX I: PSAE intercept; EX S: PSAE slope. χ² (d.f.): chi-square value (degrees of freedom); CFI: comparative fit index; TLI: Tucker–Lewis coefficient; RMSEA: root mean square error of approximation. ^aIOTM: dichotomous indicator for illicit drugs other than marijuana; includes lysergic acid diethylamide (LSD), other hallucinogens, cocaine, heroin, other narcotics, amphetamines, barbiturates and tranquilizers. Reported χ² test of model fit is for binary and ordered categorical (ordinal) outcomes. Most model fit indices are unavailable for binary processes.

Table 4 Results from full multivariate parallel process growth models for participation in sports, athletics, or exercising (PSAE) and past 30-day substance use.

	Alcohol	(P)	Cigarettes	(P)	Marijuana	(P)	IOTM ^a	(P)
Section A. Process 1: substance use estimated intercept and slope means								
SU I	2.197	(0.000)	1.688	(0.000)	1.498	(0.000)	0 ^b	
SU S1	0.262	(0.000)	0.065	(0.091)	0.003	(0.000)	-0.331	(0.000)
SU S2	-0.039	(0.285)	-0.027	(0.714)	-0.044	(0.387)	-0.316	(0.002)
Section B. Process 2: PSAE estimated intercept and slope means								
EX I	3.862	(0.000)	3.862	(0.000)	3.862	(0.000)	3.861	(0.000)
EX S1	-0.120	(0.000)	-0.123	(0.000)	-0.120	(0.000)	-0.119	(0.000)
EX S2	-0.031	(0.691)	-0.030	(0.059)	-0.031	(0.462)	-0.031	(0.356)
Section C. Substance use within-process correlations ^c (r)								
SU I ↔ SU S1	-0.402	(0.000)	-0.188	(0.000)	-0.429	(0.000)	-0.201	(0.031)
SU I ↔ SU S2	-0.191	(0.000)	-0.147	(0.000)	-0.209	(0.000)	-0.415	(0.000)
SU S1 ↔ SU S2	-0.202	(0.000)	-0.195	(0.000)	-0.138	(0.013)	0.945	(0.000)
Section D. Between-process correlations (r)								
SU I ↔ EX I	-0.015	(0.322)	-0.135	(0.000)	-0.069	(0.000)	-0.080	(0.000)
SU S1 ↔ EX S1	0.010	(0.605)	-0.139	(0.000)	-0.044	(0.010)	-0.174	(0.004)
SU S2 ↔ EX S2	0.108	(0.002)	-0.128	(0.000)	-0.014	(0.573)	-0.100	(0.442)
Section E. Direct path coefficients (β)								
SU I → EX S1	0.067	(0.001)	-0.017	(0.427)	0.062	(0.000)	0.080	(0.013)
SU I → EX S2	-0.003	(0.930)	0.048	(0.107)	0.001	(0.972)	0.000	(0.999)
EX I → SU S1	0.099	(0.000)	0.066	(0.000)	0.088	(0.000)	0.131	(0.001)
EX I → SU S2	-0.037	(0.149)	-0.014	(0.534)	-0.004	(0.814)	—	
Section F. Time-invariant controls (β)								
Male								
→ SU I	0.198	(0.000)	0.044	(0.000)	0.117	(0.000)	0.092	(0.000)
→ EX I	0.133	(0.000)	0.137	(0.000)	0.134	(0.000)	0.170	(0.000)
→ EX S2	-0.143	(0.000)	-0.130	(0.000)	-0.136	(0.000)	-0.137	(0.000)
White race/ethnicity								
→ SU I	0.158	(0.000)	0.185	(0.000)	0.035	(0.000)	0.149	(0.000)
→ EX I	0.054	(0.000)	0.057	(0.000)	0.056	(0.000)	0.088	(0.000)
Average parental education								
→ SU I	0.002	(0.875)	-0.055	(0.000)	0.024	(0.003)	— ^d	
→ EX I	0.100	(0.000)	0.099	(0.000)	0.100	(0.000)	— ^d	
→ SU S1	0.088	(0.000)	—		—		— ^d	
Participation in school athletic teams								
→ SU I	0.036	(0.001)	-0.141	(0.000)	-0.086	(0.000)	-0.059	(0.000)
→ EX I	0.663	(0.000)	0.661	(0.000)	0.661	(0.000)	0.461	(0.000)
→ EX S1	-0.526	(0.000)	-0.522	(0.000)	-0.516	(0.000)	-0.317	(0.000)
Full-time student at age 19/20								
→ SU S1	0.234	(0.000)	0.006	(0.719)	0.097	(0.000)	0.135	(0.007)
→ SU S2	-0.056	(0.019)	-0.075	(0.000)	-0.045	(0.012)	-0.119	(0.199)
→ EX S1	0.071	(0.001)	0.063	(0.003)	0.071	(0.001)	0.073	(0.002)
→ EX S2	0.084	(0.001)	0.093	(0.001)	0.086	(0.001)	0.087	(0.002)
Section G. Model fit statistics								
Model N	11 741		11 741		11 741		11 741	
χ ² (d.f.)	288.934 (64)		259.784 (65)		210.716 (65)		—	
CFI, TLI	0.990, 0.985		0.993, 0.990		0.993, 0.990		—	
RMSEA	0.017		0.016		0.014		—	

Intercepts and slopes shown using non-standardized values. Standardized values shown for correlations and coefficients. For alcohol, cigarettes and marijuana, the coefficients are expressed as traditional linear regression estimates. For IOTM, the logistic model for categorical outcomes with a numerical integration algorithm was used; thus, estimates use logits. For all substances other than marijuana, models simultaneously controlled for gender, race/ethnicity, parental education, college status and school athletic team participation. For IOTM, the model controlled for gender, race/ethnicity, college status and school athletic team participation. SU I: substance use intercept; SU S: substance use slope; EX I: PSAE intercept; EX S: PSAE slope. χ² (d.f.): chi-square value (degrees of freedom); CFI: comparative fit index; TLI: Tucker–Lewis coefficient; RMSEA: root mean square error of approximation. ^aIOTM: dichotomous indicator for illicit drugs other than marijuana; includes lysergic acid diethylamide (LSD), other hallucinogens, cocaine, heroin, other narcotics, amphetamines, barbiturates and tranquilizers. Most model fit indices are unavailable for binary processes (as both a continuous and dichotomous outcome have been modeled together, χ² test of model fit is also unavailable). ^bMplus fixes the mean of intercept growth factors for categorical variables at zero. ^cWithin-process correlations for exercise ranged from: EX I ↔ EX S1 = -0.288 to -0.292 (P = 0.000); EX I ↔ EX S2 = -0.165 to -0.172 (P = 0.000); EX S1 ↔ EX S2 = -0.205 to -0.211 (P = 0.001). ^dEstimates for parental education obtained from the multivariate model excluding school athletic team participation were: → SU I = -0.018 (P = 0.205); → EX I = 0.191 (P < 0.001); → SU S1 not modeled.

Past 30-day marijuana use frequency and PSAE

Higher PSAE was associated with lower age 18 marijuana use frequency in bivariate and multivariate models (multivariate model SU I \leftrightarrow EX I, $r = -0.069$, $P < 0.001$). PSAE increases were related significantly to decreases in marijuana use to age 21/22 (multivariate model SU S1 \leftrightarrow EX S1, $r = -0.044$, $P = 0.010$) but no significant association was observed between ages 21/22 and 25/26.

Past 30-day IOTM use prevalence and PSAE

At age 18, higher PSAE was associated with lower IOTM use in bivariate and multivariate models (multivariate model SU I \leftrightarrow EX I, $r = -0.080$, $P < 0.001$). PSAE increases were related to decreased IOTM use to age 21/22 (multivariate model SU S1 \leftrightarrow EX S1, $r = -0.174$, $P = 0.004$) but were not related significantly from ages 21/22 to 25/26.

DISCUSSION

Results indicated that higher initial PSAE related to lower initial past-30-day cigarette and marijuana use frequency and IOTM use prevalence; lower initial substance use then corresponded with lower use throughout early adulthood. Further, as individuals increased PSAE, cigarette, marijuana and IOTM use frequency decreased. PSAE was not associated significantly with age 18 alcohol use frequency. However, school athletic team participation at age 18 was associated with higher alcohol use frequency (but lower use frequency of cigarettes and marijuana and IOTM prevalence). The magnitude of the observed associations was not particularly large; however, results indicate a consistent relationship indicative of somewhat lowered substance use frequency/prevalence associated with increased PSAE in early adulthood.

Substance abuse prevention focuses on preventing, delaying onset or moderating problems associated with substance use [45]. The importance of delaying onset is well documented. Early onset relates to heavier and longer use of the original substance, as well as problematic use of other substances [46]. Life-time drug abuse and dependence is reduced significantly by each year use onset is delayed [47]. Lower past-30-day use at age 18 does not equal delayed onset; however, lower use at age 18 and throughout early adulthood represents a similar, desired public health outcome. This study indicated that lower age 18 substance use related to lower growth rates, and higher PSAE related to overall lower substance use at age 18 and to early adulthood. Efforts to encourage all adolescents to increase enjoyment of and participation in general exercise may result in lower substance use and abuse as youth move into early adulthood. The observed PSAE and substance use slopes in the current study are

similar to general population trajectories found in previous studies [31,48–50], lending support to these results.

In this study, PSAE was a single measure emphasizing participation; it did not capture physiological effects of exercise. Thus, obtained results could be related to (i) an individual's time being filled with participating in exercise versus participating in substance use; (ii) social and peer influences from different groups; (iii) physiological effects of exercise; and (iv) a combination of the above, etc. A constellation of environmental, familial, peer and genetic factors relate to substance use [51–55]; PSAE may be affected by similar factors. However, the finding that as individuals increased their PSAE there were significant decreases in their use of cigarettes, marijuana and IOTM in early adulthood may reflect a health promotion intervention opportunity.

Identification of significant differences in the normative trajectory of substance use based on type of physical activity could strengthen substance abuse prevention and treatment efforts and possibly identify at-risk populations. Participation in team sports related to higher alcohol use frequency at age 18, and higher initial frequency related to significantly higher frequency throughout young adulthood. High school team sports participants may be in need of targeted alcohol prevention efforts. Previous research indicates that middle school youth with delinquent histories tend to drop out of school athletics, leaving a group with comparatively higher social conformity [56]. Social conformity may increase the likelihood of conforming to perceived substance use norms, including peer norms regarding alcohol use as a team bonding/social activity. Perceived norms (accurate or not) have been found consistently to relate to young adult alcohol use [57,58]. By the senior year of high school, school athletic team participation also may be limited to students who are the most skilled and competitive [59], characteristics that research has found to be associated with increased alcohol use [60].

Limitations

These findings should be considered within their limitations. Analyses could not relate early life exercise participation and age of substance use onset, and analyses did not investigate relationships between substance use quantity and PSAE. Past-30-day substance use frequency rates were chosen as the time-frame to minimize endogeneity with PSAE. PSAE and drug use measures were single-item, and students self-reported participation in exercise and team sports in broad, general terms. While it would be preferable to have more specific information, the measures probably capture much of the valid interindividual variation. (Reliabilities of the single-item measures of PSAE and sports are each estimated at 0.60 based on

longitudinal data; because there is no longitudinal data for school athletic team participation, no reliability estimate is available.) The current study did not measure type of school team sport nor level of team sports participation after age 18. Research indicates that type of team sport relates significantly to substance use [21,61,62]. However, individuals who participate in team-based sports in early adulthood were probably involved in such activities at the high school level (although some school districts do not offer school-based team sports, and the current study may have excluded youth involved in non-school based team sports). Other limitations are that analyses do not include high school dropouts (dropout rates range between 13% and 20% nationally) [55], the MTF longitudinal sample is subject to attrition, and all data were self-report. Finally, as noted previously, alcohol, cigarette and marijuana use frequency outcomes were treated as normally distributed interval measures (an assumption that is clearly not valid). To investigate the possible implications of misspecification, IOTM/PSAE models were estimated using IOTM as both continuous and linear (because this outcome exhibited the strongest non-normal distribution, we considered it the best to use for alternative estimation). The results of interest for the linear model (correlations between the intercepts and slopes of the opposing processes) were not substantively different from those obtained from the model where IOTM was specified as a categorical variable. The limitations notwithstanding, the current study may be one of the first that uses longitudinal data to control for team sports participation while examining growth trajectories for exercise participation in general and substance use in a nationally representative sample of young adults.

CONCLUSIONS

PSAE was related moderately and negatively to cigarette and marijuana use frequency and IOTM use prevalence at age 18, and growth in PSAE was related to decreased growth in the use of these three substances in early adulthood. Understanding the specific mechanisms by which PSAE may relate to lower substance use will require further research; however, the processes do appear to be related. Encouraging the enjoyment of and participation in general exercise may relate to lower substance use throughout adolescence and early adulthood.

Declarations of interest

None.

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