

Legal Performance-Enhancing Substances and Substance Use Problems Among Young Adults

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abstract

BACKGROUND: Legal performance-enhancing substance(s) (PES) (eg, creatine) are widely used among adolescent boys and young men; however, little is known about their temporal associations with substance use behaviors.

METHODS: We analyzed prospective cohort data from the National Longitudinal Study of Adolescent to Adult Health, Waves I to IV (1994–2008). Logistic regressions were used to first assess adolescent substance use (Wave I) and use of legal PES (Wave III) and second to assess use of legal PES (Wave III) and subsequent substance use–associated risk behaviors (Wave IV), adjusting for potential confounders.

RESULTS: Among the sample of 12 133 young adults aged 18 to 26 years, 16.1% of young men and 1.2% of young women reported using legal PES in the past year. Adolescent alcohol use was prospectively associated with legal PES use in young men (odds ratio 1.39; 95% confidence interval [CI] 1.13–1.70). Among young men, legal PES use was prospectively associated with higher odds of problematic alcohol use and drinking-related risk behaviors, including binge drinking (adjusted odds ratio [aOR] 1.35; 95% CI 1.07–1.71), injurious and risky behaviors (aOR 1.78; 95% CI 1.43–2.21), legal problems (aOR 1.52; 95% CI 1.08–2.13), cutting down on activities and socialization (aOR 1.91; 95% CI 1.36–2.78), and emotional or physical health problems (aOR 1.44; 95% CI 1.04–1.99). Among young women, legal PES use was prospectively associated with higher odds of emotional or physical health problems (aOR 3.00; 95% CI 1.20–7.44).

CONCLUSIONS: Use of legal PES should be considered a gateway to future problematic alcohol use and drinking-related risk behaviors, particularly among young men.



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WHAT'S KNOWN ON THIS SUBJECT: Substance use is common among adolescents, and performance-enhancing substances (PES) are widely used among young men. In contrast to research documenting the adverse consequences of steroid use, investigation of the potential adverse outcomes associated with legal PES has been neglected.

WHAT THIS STUDY ADDS: Alcohol use among adolescent boys is prospectively associated with legal PES use in young adulthood. Among men, legal PES use is prospectively associated with subsequent problematic alcohol use and drinking-related risk behaviors after accounting for adolescent substance use.

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Performance-enhancing substances (PES) are often used to improve athletic performance,¹ as well as used for the purpose of altering one's appearance to a more muscular and lean body type.² There is inconsistency of the legal status of PES in federal and state laws in the United States. For the purposes of this article, we refer to protein powders, creatine monohydrate, dehydroepiandrosterone, and amino acids, as "legal PES" and anabolic-androgenic steroid (AAS) derivatives, when not prescribed for medical purposes, as "illegal PES." Much research has been conducted on the adverse health outcomes associated with AAS, including mood disorders, aggression, and violence,^{3,4} and substance use disorders,⁵ as well as several health issues related to the cardiovascular,⁶⁻⁸ neuroendocrine,⁹ musculoskeletal,¹⁰ renal, liver,⁷ and immune¹¹ systems of the body. However, much less is known about the possible adverse mental, physical, and social health outcomes associated with legal PES use, particularly among young adults.

Adolescence and young adulthood may be particularly salient developmental periods for experimentation with legal PES.¹ However, research relating to legal PES use among adolescents and young adults has typically been focused on establishing prevalence rates and predictors rather than explicating the risk inherent to these behaviors, both legal and otherwise.¹² Notwithstanding, evidence from a sample of adolescents in Minnesota indicates that 35% of boys and 21% of girls use protein powders and/or shakes and 10.5% of boys and 5.5% of girls use other PES (eg, creatine monohydrate, amino acids, hydroxy methylbutyrate, dehydroepiandrosterone, or growth hormone) to increase their muscle mass or tone.¹³ In addition, among college athletes and nonathletes, prevalence rates of past-year use of

PES are relatively high. For example, 46% of male nonathletes and 56% of male athletes, as well as 25% of female nonathletes and 30% of female athletes, are using these substances.¹⁴ Predictors of legal PES use include sports participation, inaccurate body weight perception, and weight gain behaviors.¹⁵ Importantly, there appears to be a subsequent progression and predictive relationship from legal PES use (eg, protein and creatine monohydrate) to illegal PES use (eg, AAS).¹⁶ Substance use, including alcohol use,¹⁵ binge drinking, and drug use,¹⁷ is also associated with muscularity concerns and muscularity-oriented behaviors, including PES use. Of the preliminary work used to assess the consequences of legal muscle-enhancing, weight loss, or energy supplements use among children, adolescents, and young adults, research has revealed there is a significant increase in the risk of a severe medical event. This may include emergency department visits, disability, or premature death.¹⁸

In concert with the elevated risk for experimentation with legal PES, young adulthood is also associated with peak risk for the onset and intensification of legal and illegal substance use behaviors.^{19,20} Data from major adolescent substance use tracking surveys, including the Centers for Disease Control and Prevention, continue to reveal that alcohol use, drinking to intoxication, binge drinking (≥ 5 alcoholic drinks in a row in men or ≥ 4 in women), cigarette use, and marijuana use are common substance use behaviors among young people.^{21,22} In addition, empirical research continues to reveal the high prevalence rates of alcohol, tobacco, and marijuana use among adolescents and young adults.²⁰ Although these behaviors occur among both young adult men and young adult women, they are overall more common among young

adult men.^{19,22} Alongside well-established adverse health outcomes,^{23,24} social problems (eg, legal problems, violence, work problems, impulsivity),²⁵⁻²⁷ and the significant economic impact,²⁸ it has recently been shown that substance use, and polysubstance use in particular, is associated with muscularity concerns,^{17,24} steroid and diet pill use, fasting, and purging²⁹ among adolescent boys and young adult men. Furthermore, muscle dysmorphia, the pathologic pursuit of muscularity, which is common among young adult men,^{30,31} is characterized by PES use as a means to alter their body.³¹⁻³³ Muscle dysmorphia is also associated with additional substance use disorders.³³ This suggests a particularly potent link between muscularity-oriented pursuits, including legal and illegal PES use, and substance use.

This relationship may be explained theoretically by using the gateway hypothesis. This theory posits that substance use among adolescents follows a sequential process in which the initial use of 1 licit substance can lead to the use of additional, illicit substances later in life.^{34,35} Within this framework, experimentation with substances during adolescence may lead to legal PES use given that legal PES are easily accessible, unregulated,¹² and socially sanctioned among adolescents given their high rates of use.¹³ It can then be conceived that alcohol use can act as a gateway to legal PES use, which can then lead to further problematic alcohol use, drinking-related risk behaviors, cigarette smoking, and marijuana use, as well as polysubstance use among adolescents and young adults.

Guided by this expanded gateway hypothesis that includes legal PES as a gateway substance, we had 2 specific aims. First, we aimed to investigate whether alcohol use, cigarette use, and marijuana use were

prospectively associated with legal PES use in young adulthood. Second, in ascertaining the directionality of this prospective association, we aimed to investigate whether use of legal PES in young adulthood, controlling for baseline alcohol use, cigarette use, and marijuana use, was prospectively associated with problematic alcohol use, drinking-related risk behaviors, cigarette smoking, and marijuana use at a 7-year follow-up. First, we hypothesized that there would be significant associations between adolescent alcohol use, cigarette use, and marijuana use with legal PES use in young adulthood. Second, we hypothesized that legal PES use in young adulthood would be prospectively associated with problematic alcohol use and drinking-related risk behaviors, cigarette smoking, and marijuana use at a 7-year follow-up given the association between legal PES use and substance use behaviors.¹⁷

METHODS

Study Population

In this study, we use cross-sectional data from the National Longitudinal Study of Adolescent to Adult Health (Add Health). Add Health is a longitudinal cohort study of a nationally representative sample of adolescents in the United States who are followed into adulthood.^{36,37} The baseline sample was collected in 1994 to 1995 when subjects were adolescents (11–18 years) and used systematic sampling methods and implicit stratification to ensure that the high schools ($N = 80$) and paired middle schools selected were representative of US schools with respect to region of the country, urbanicity, size, type, and ethnicity. For this particular study, we used the nationally representative, restricted-use samples from Wave III (18–26 years; 2001–2002) and Wave IV (24–32 years; 2008). The University

of North Carolina Institutional Review Board approved all Add Health study procedures. Further details about the study design can be found elsewhere.³⁷

Measures

The primary measures of this study include baseline alcohol use, cigarette use, and marijuana use, legal PES use in the past year, binge drinking in the past 12 months, drinking-related risk and problematic behaviors, cigarette smoking in the past 30 days, and marijuana use in the past 30 days. Covariates include age, sex, race and/or ethnicity, household income, BMI, and baseline substance use (alcohol, cigarette, and marijuana) (see Supplemental Table 4 for full description of the measures).

Statistical Analysis

Data analysis was performed by using Add Health's preconstructed sample weights to provide a nationally representative sample.^{38,39} Comparisons between legal PES users versus nonusers of legal PES in descriptive characteristics were calculated by using Pearson's χ^2 tests for categorical variables and independent samples t tests for continuous variables, stratified by sex. Multiple logistic regressions were used to identify baseline (Wave I) adolescent substance use (alcohol, cigarette, marijuana) prospectively associated with legal PES use in young adulthood (Wave III), adjusting for age, race and/or ethnicity, and household income. Multiple logistic regressions were used to assess legal PES use (Wave III) and subsequent substance use outcomes (alcohol, cigarette, marijuana) at Wave IV, adjusting for substance use at baseline (Wave I alcohol, cigarette, and marijuana) and Wave III whenever possible (binge drinking, cigarette, and marijuana use). All models included the covariates age, race and/or ethnicity, household income, and BMI.^{39–41} Analyses were stratified by sex given the different

rates of legal PES use in young men and young women.¹ The significance level for all analyses was set at $\alpha = .05$. Analyses were conducted by using Stata 15.0 (Stata Corp, College Station, TX).⁴²

RESULTS

Demographic characteristics of the sample ($N = 12\,133$) by use of legal PES at age 18 to 26 years are reported in Table 1. Overall, 16.1% of young men and 1.2% of young women reported using legal PES in the past year. The sample was racially and ethnically diverse. A higher proportion of male legal PES users were white and had a higher mean household income than that of nonusers. Female legal PES users had a lower BMI on average than that of nonlegal PES users.

At baseline, both male and female legal PES users had a greater likelihood of ever using alcohol and smoking cigarettes. Male legal PES users had a greater likelihood of ever using marijuana, whereas female nonlegal PES users had a greater likelihood of ever using marijuana. The unadjusted substance use outcomes at the 7-year follow-up (ages 24–32 years) are also listed in Table 1. The likelihood of reporting all of the alcohol-related behaviors was higher in young men who had reported use of legal PES 7 years earlier compared with male nonusers. Among young women, those who had reported earlier use of legal PES had higher rates of hurting themselves or engaging in risky behaviors while under the influence of alcohol compared with nonusers at the 7-year follow-up, but there were not significant differences in other alcohol-related behaviors. Cigarette smoking and marijuana use at the 7-year follow-up were not associated with earlier endorsement of legal PES use among young men or young women.

TABLE 1 Demographic and Health Characteristics of 12 133 Young Adult Participants in Add Health, Stratified by Legal PES Use

	Young Adult Men			Young Adult Women		
	Legal PES Use	No Legal PES	<i>P</i>	Legal PES Use	No Legal PES	<i>P</i>
	<i>n</i> = 878	<i>n</i> = 4640		<i>n</i> = 89	<i>n</i> = 6526	
Demographic characteristics (Wave III, 18–26 y)						
Age, y, mean ± SE	21.8 ± 0.1	21.9 ± 0.1	.149	21.4 ± 0.3	21.7 ± 0.1	.364
Race and/or ethnicity, %			.002*			.222
White (non-Hispanic)	77.9	67.1	—	74.3	68.6	—
Black or African American (non-Hispanic)	8.9	15.2	—	6.4	16.0	—
Hispanic	9.1	12.6	—	14.3	11.3	—
Asian American or Pacific Islander (non-Hispanic)	2.5	3.7	—	3.4	3.1	—
American Indian	0.5	0.6	—	1.6	0.5	—
Other	1.1	0.9	—	0.0	0.6	—
Household income, US \$ (Wave I), mean ± SE	52 435 ± 2110	44 184 ± 1518	<.001*	58 547 ± 8696	46 645 ± 1523	.171
BMI, mean ± SE	26.4 ± 0.2	26.4 ± 0.2	.948	23.8 ± 0.8	26.4 ± 0.2	.003*
Baseline substance use (ever use, Wave I, 11–18 y), %						
Alcohol	65.00	55.00	<.001*	64.10	55.30	.233
Cigarette	64.5	57.0	<.001*	60.9	57.7	.636
Marijuana	31.9	27.0	.058	22.3	24.4	.640
Substance use outcomes (Wave IV, 24–32 y)						
Alcohol, %						
Binge drinking in past 12 mo	70.8	55.3	<.001*	55.6	43.2	.087
Hurt or risky behaviors while under the influence of alcohol	44.5	28.5	<.001*	39.2	23.2	.027*
Legal problems while under influence of alcohol	40.3	30.8	.017*	16.7	13.6	.678
Cut down on activities and socialization that interfere with alcohol use	11.9	6.0	<.001*	9.4	3.4	.264
Continued to use alcohol despite emotional or physical health problems	12.6	8.2	.006*	16.0	5.6	.097
Cigarette smoking in past 30 d, %	39.7	43.1	.186	27.6	34.2	.302
Marijuana use in past 30 d, %	24.2	21.7	.225	19.9	12.6	.252

All means and percentages are calculated with weighted data to reflect the representative proportion in the target US population. —, not applicable.

* *P* < .05

The prospective associations between baseline substance use and legal PES use in young adulthood are reported in Table 2. Among young men, adolescent alcohol use was prospectively associated with legal PES use (odds ratio [OR] 1.39; 95% confidence interval [CI] 1.13–1.70). Cigarette smoking and marijuana use were not associated with legal PES use among young men. Any adolescent substance use was not prospectively associated with legal PES use among young women.

Reported in Table 3 are the prospective associations between use of legal PES in young adults 24 to 32 years of age and incident substance use at the 7-year follow-up, when adjusted for age, race and/or ethnicity, household income, BMI, Wave III behaviors when available (binge drinking, cigarette smoking, and marijuana use), and baseline (Wave I) substance use behaviors. Among young men, legal PES use was prospectively associated with higher

odds of all 5 problematic alcohol use and drinking-related risk behaviors, including binge drinking (adjusted odds ratio [aOR] 1.35; 95% CI 1.07–1.71), injurious and risky behaviors (aOR 1.78; 95% CI 1.43–2.21), legal problems (aOR 1.52; 95% CI 1.08–2.13), cutting down on activities and socialization (aOR 1.91; 95% CI 1.36–2.78), and emotional or physical health problems (aOR 1.44; 95% CI 1.04–1.99). Among young women, legal PES was prospectively associated with higher odds of only emotional or physical health problems (aOR 3.00; 95% CI 1.20–7.44). Legal PES use was not associated with cigarette smoking or marijuana use in young men or young women, except that it was marginally associated with lower odds (aOR 0.75; 95% CI 0.58–0.88) of cigarette smoking in young men.

DISCUSSION

Our overall aim of this study was to investigate the associations between legal PES use and substance use behaviors across adolescence and young adulthood. Our first specific aim was to investigate whether adolescent alcohol use, cigarette use, and marijuana use were prospectively associated with legal PES use in young adulthood. Our second specific aim was to investigate whether use of legal PES in young adulthood, controlling for baseline alcohol use, cigarette use, and marijuana use, was prospectively associated with problematic alcohol use, drinking-related risk behaviors, cigarette smoking, and marijuana use at the 7-year follow-up.

Results from our first aim reveal that alcohol use in adolescence is prospectively associated with legal PES use in young adulthood among boys. There were no significant associations between substance use behaviors and prospective legal PES use among girls. Results from our second aim reveal that, similarly, young adult men who used legal PES

TABLE 2 Associations Between Adolescent Baseline Predictors and Young Adult Legal PES Use

Baseline Predictors (Wave I, Ages 11–18)	Boys		Girls	
	OR (95% CI)	P	OR (95% CI)	P
Demographic				
Age	0.93 (0.88–0.98)*	.005*	0.90 (0.74–1.10)	.317
Race and/or ethnicity				
White (referent)				
Black or African American	0.54 (0.39–0.74)*	<.001*	0.41 (0.16–1.07)	.069
Hispanic	0.73 (0.53–0.99)*	.047*	1.26 (0.46–3.44)	.645
Asian American or Pacific Islander	0.68 (0.43–1.06)	.092	1.04 (0.30–3.57)	.950
American Indian	0.99 (0.45–2.19)	.982	4.12 (0.63–27.08)	.139
Other race and/or ethnicity	1.20 (0.42–3.39)	.731	—	—
Household income	1.00 (1.00–1.00)	.027	1.00 (1.00–1.00)*	.031*
Substance use				
Alcohol	1.39 (1.13–1.70)*	.002*	1.76 (0.91–3.40)	.093
Cigarette	1.18 (0.94–1.48)	.158	1.02 (0.51–2.01)	.956
Marijuana	1.13 (0.88–1.45)	.315	0.73 (0.39–1.36)	.321

—, not applicable.

* $P < .05$.

had significantly greater likelihood of engaging in all 5 problematic alcohol use and drinking-related risk behaviors after 7 years. For young adult women, those who used legal PES had significantly greater likelihood of engaging in 1 of the 5 problematic alcohol use and drinking-related risk behaviors. Legal PES use among young men and young women was not significantly associated with later increased use of marijuana, and legal PES use was associated with later lowered odds of cigarette smoking among young adult men.

Guided by the gateway theory, which posits that substance use follows a pattern among adolescents into young adulthood,^{34,35} the results provide partial support for the hypotheses of this study. Alcohol use among adolescent boys appears to increase the likelihood of using legal PES, whereas subsequent legal PES use among young adult men appears to increase the likelihood of adopting problematic alcohol use and drinking-related risk behaviors among men in later years. Although evidence to date has demonstrated that early

engagement in substance use results in a greater array of subsequent substance use,^{34,35,43–45} it is suggested in our findings that legal PES must be integrated into the gateway hypotheses of substance use. To date, legal PES have not been largely considered as part of the spectrum of substances used among adolescents, have not been subject to the same regulatory scrutiny as other substances known to be linked to subsequent substance use, and are freely available over the counter to adolescents. Clearly, the robust reciprocal temporal relationship between substance use and legal PES suggests that each may serve as a gateway for the other.

In existing evidence, it is suggested that extreme body image ideals and disorders (eg, eating disorders, body dysmorphic disorder, and muscle dysmorphia) among boys and men may drive PES use in pursuit of a muscular and lean ideal.⁴⁶ Boys and men who are seeking this body image ideal may subscribe to more traditional norms of masculinity, such as risk-taking and emotional control,^{47,48} which may include problematic alcohol use and drinking-related risk behaviors. Additionally, research has revealed a significant positive association between substance use behaviors, including alcohol use and PES use, among men who experience eating disorders⁴⁹ and muscle dysmorphia.^{31–33,50} This further supports the notion that polysubstance use may be common among young adult men. Importantly, biological mechanistic explanations of the association between these substances are difficult to elucidate because of the known error and inconsistency in PES labeling and content.^{51,52} Therefore, it is posited that the association between these substances are likely due to psychological, behavioral, and/or sociocultural influences.

Overall, legal PES use was more prevalent among young adult men

TABLE 3 Prospective Association Between Legal PES in Young Adults 24 to 32 Years of Age and Incident Substance Use at 7-Year Follow-up, Adjusted for Covariates

Self-Reported Health Outcomes	Men		Women	
	aOR ^a (95% CI)	P	aOR ^a (95% CI)	P
Alcohol				
Binge drinking in past 12 mo	1.35 (1.07–1.71)*	.012*	1.04 (0.59–1.86)	.882
Hurt or risky behaviors while under the influence of alcohol ^b	1.78 (1.43–2.21)*	<.001*	1.78 (0.99–3.23)	.055
Legal problems while under influence of alcohol ^b	1.52 (1.08–2.13)*	.016*	1.04 (0.33–3.29)	.947
Cut down on activities and socialization that interfere with alcohol use ^b	1.91 (1.36–2.78)*	<.001*	2.44 (0.73–8.16)	.146
Continued to use alcohol despite emotional or physical health problems ^b	1.44 (1.04–1.99)*	.029*	3.00 (1.20–7.44)*	.018*
Cigarette smoking in past 30 d	0.75 (0.58–0.98)*	.038*	0.86 (0.34–2.17)	.747
Marijuana in past 30 d	0.88 (0.63–1.22)	.445	1.13 (0.40–3.15)	.816

^a Adjusted for age, race and/or ethnicity, household income, BMI, baseline alcohol, baseline cigarette, baseline marijuana, and risk behavior at Wave III.

^b Question asked only at Wave IV.

* $P < .05$.

compared with that of young adult women. This aligns with previous research^{13,14} and may provide additional support for the notion that men seek a body ideal that is focused on greater muscle mass⁵³ and overall improved athletic performance.¹ Similarly, use of alcohol, including binge drinking and drinking to intoxication, is more prevalent among young men compared with young women.¹⁹ In this study, we found that both young men who used legal PES and those who had not used legal PES had greater prevalence of all alcohol use and drinking-related risk and problematic behaviors compared with young women, with 1 exception (female legal PES users had greater prevalence of continuing to drink despite emotional or physical health problems compared with male legal PES users). Alcohol use is socialized to be a part of the male gender role, and there are social sanctions placed on women that discourage drinking behaviors.⁵⁴ Furthermore, the use of legal PES among women may be less socially acceptable because of the female body ideal being one primarily focused on thinness.⁵⁵ Thus, social expectations and gender norms may provide additional explanation for the association between these forms of substance use.

With the results from this study, we provide further confirmation that men often experience greater physical and behavioral problems associated with alcohol use,⁵⁶ particularly young men who have previously used legal PES. This is especially concerning because men have higher rates of death and incur a greater rate of total burden measured by disability-adjusted life years associated with alcohol compared with women.⁵⁷ Alcohol use also has a significant burden on US gross domestic product, health care costs, and law enforcement costs.²⁸ With these results, we provide further support for legislation that would provide greater oversight of, and restrict

access to, legal PES among particularly vulnerable populations (eg, adolescents).¹² These prevention methods may ultimately reduce problematic alcohol use and drinking-related risk behaviors among adults who have previously used legal PES.

A surprising finding from this study is that legal PES use acted as a protective factor for cigarette smoking among men. This may not be surprising given that cigarette smoking is less prevalent among men who participate in regular athletic activities.⁵⁸ Cigarette smoking may also be used as a weight loss behavior⁵⁹ and thus may not have beneficial weight-related side effects for young men aiming to achieve a larger, more muscular body.

Despite the important findings of this study, there are limitations to be noted. First, the legal PES use variable conflates multiple substances (eg, “creatine monohydrate or androstenedione”).^{60,61} This limits the ability to identify the outcomes of each specific substance. Future research should aim to investigate the nuances between these substances. Second, several of the problematic alcohol use and drinking-related risk behaviors were not asked of participants in Wave III of data collection. This did not allow for them to be controlled for during analyses; thus, we could not examine the relative increase in rates of these behaviors from Wave III to Wave IV. On the other hand, analyses did adjust for Wave III rates of binge drinking, cigarette smoking, and marijuana use, as well as baseline substance use, and thus bolsters our confidence that legal PES acts as a risk factor for increased use of these behaviors and is not merely a correlate. Third, it is important to investigate prospective illegal and/or other substance use (eg, cocaine, heroin, and nonmedical use of prescription drugs) behaviors associated with legal PES use. The

wording of the measures investigating these substances in the Add Health survey did not allow for clear prospective analysis. Fourth, although the Add Health legal PES measure directly names “creatine monohydrate or andro” as legal substances, there are limitations and nuances to labeling these substances as legal versus illegal. Finally, responses from participants are based on self-report; therefore, responses may be impacted by social desirability bias.

CONCLUSIONS

With this study, we found that alcohol use during adolescence was prospectively associated with legal PES use in young adulthood. Additionally, legal PES use was prospectively associated with increased likelihood of problematic alcohol use and drinking-related risk behaviors at a 7-year follow-up. These associations were particularly strong for adolescent boys and young adult men. These results provide further evidence in support of the gateway theory and prospective health risk behaviors associated with legal PES and substance use. This can inform policy on further regulation of legal PES, particularly among minors. It is important for medical providers and clinicians to assess problematic alcohol use and drinking-related risk behaviors among young adult men who have previously used legal PES.

ABBREVIATIONS

AAS: anabolic-androgenic steroid
Add Health: National Longitudinal Study of Adolescent to Adult Health
aOR: adjusted odds ratio
CI: confidence interval
OR: odds ratio
PES: performance-enhancing substance(s)

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