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The Lifetime Prevalence of Anabolic-Androgenic Steroid Use and Dependence in Americans: Current Best Estimates

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Abstract

Background and Objectives—Although various surveys have tracked the prevalence of anabolic-androgenic steroid (AAS) use in American teenagers and young adults, no recent surveys have assessed the lifetime prevalence of AAS use in Americans overall. We therefore analyzed serial youth-survey data to derive estimates of the lifetime prevalence of AAS use in the current American general population.

Methods—We first determined the distribution of age of onset of AAS use, based on pooled data from nine studies. Using this distribution, we then developed equations to project the eventual lifetime prevalence of AAS use among young survey respondents, once they aged and completed the period of risk for initiating AAS. We similarly calculated the denominator of lifetimes of risk for AAS use in the total American population. We next applied these equations to four independent national youth datasets to derive current American general-population estimates for lifetime AAS use. Finally, using data from 10 pooled studies, we estimated the lifetime prevalence of AAS dependence among AAS users.

Results—Age-of-onset studies consistently showed that AAS use begins later than most drugs, with only 22% of users (95% confidence interval: 19%–25%) starting before age 20. Applying the age-of-onset findings to national youth datasets, we estimated that among Americans currently age 13 to 50 years, 2.9–4.0 million have used AAS. Within this group, roughly 1 million may have experienced AAS dependence.

Conclusions and Scientific Significance—Although subject to various limitations, our estimation techniques suggest a surprisingly high prevalence of AAS use and dependence among Americans.

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Declaration of interest

Dr. Pope has testified as an expert witness in five cases involving anabolic-androgenic steroid use during the last three years. The authors report no other conflicts of interest. The authors alone are responsible for the content and writing of this paper.

INTRODUCTION

A growing number of individuals worldwide have used anabolic-androgenic steroids (AAS) to gain muscle or lose body fat.¹ Some users go on to develop AAS dependence, and continue taking highly supraphysiologic doses of these drugs for years.^{2,3} AAS use and dependence may cause serious adverse effects, including especially cardiovascular, neuroendocrine, and psychiatric disorders,^{1,4} which likely increase premature mortality.⁵ However, to quantify the public health threat from these effects, we need to know the prevalence of AAS use.

For classical drugs of abuse such as cannabis or cocaine, extensive prevalence data exist,⁶ because these drugs have been around for a long time. But AAS are arguably the youngest and least studied of the world's major abused substances. Although some elite athletes used AAS as early as the 1950s, the great majority of rank-and-file AAS users began use after 1980 in United States and after 1990 elsewhere.⁷ Consequently, the age distribution of AAS users has not yet reached a steady state. Users at the chronological leading edge of the group – those who first tried AAS as youths in the 1980s – are only now passing into middle age, while new users continue to enter at the bottom of the age range. Thus future decades will witness steadily increasing numbers of aging AAS users. This dynamic situation combines with sparse data to complicate estimations of prevalence.

Finally, there is another methodological problem peculiar to surveys of AAS use. When asked whether they have used “steroids,” survey respondents may confuse illicit AAS with corticosteroids or with over-the-counter nutritional supplements that they thought were “steroids,” thus causing false-positive responses. As we have detailed previously,⁸ these false-positives may inflate AAS prevalence estimates.

Despite these challenges, it remains important to develop working prevalence estimates. Here we attempt to approximate the number of people in the United States who have used AAS at some time in their lives. We focus on Americans for several reasons. First, the United States is the most populous country with significant AAS use,⁹ and thus accounts for the largest number of AAS users. Second, widespread illicit AAS use arose in the United States ahead of other countries, fueled in part by the early appearance of American underground guides to AAS use⁷ and by a growing focus on male body image in American culture.¹⁰ This latter trend, which began to evolve in the 1970s and 1980s, is exemplified by proliferating muscular male bodies in American movies, television dramas, fitness magazines, and advertising, and even by the growing muscularity of American action toys such as “G.I. Joe.”¹¹ Because AAS use arose earlier in America than elsewhere, the United States population contains a larger proportion of AAS users who are already reaching middle age, and who are likely more vulnerable to adverse effects. Third, unlike many countries possessing recent household surveys of AAS use,^{12,13} the United States lacks any general-population survey of AAS use, to our knowledge, since 1994.¹⁴

METHODS

Overview

Although the United States lacks recent general-population surveys of AAS, we found four American *youth* surveys qualifying for analysis,^{15–18} in that they: 1) utilized national samples; 2) were repeated over multiple survey years; and 3) inquired about lifetime AAS use, rather than merely past-year use or current use. We then developed mathematical methods to extrapolate from these young survey populations to generate prevalence estimates for current overall American population.

Our methods involved three steps. First, we located published studies of AAS users to that assessed the age of onset of AAS use in each study participant. Using a random effects model,¹⁹ we then estimated the mean cumulative proportion of individuals across studies who had initiated AAS use at each year of age. Second, we developed equations to apply this age-of-onset distribution to AAS-prevalence data from youth surveys. Knowing the age distribution of the youths in a given survey, we could use these equations to project these youths' ultimate lifetime prevalence of AAS use by the time that they grew older and completed the period of risk for initiating AAS. We applied similar methods to United States census data to calculate a denominator of "lifetimes of risk" for AAS use in the total American population. We then combined these calculations to estimate the lifetime prevalence of AAS use in the general American population today. Third, using data from 10 pooled studies, we estimated the lifetime prevalence of AAS dependence among AAS users.

For full details of these methods, including an explanation of the equations that we developed for the above mathematical models, please see the detailed presentation provided in the online Supplemental Materials.

RESULTS

Age of onset of AAS use

We located nine studies of AAS users published since 2000 in which age of onset of use was assessed. Five studies assessed American users; of these, four are published^{20–23} and one is in progress (Pope, et al., unpublished observations). One of these five studies²¹ also included non-American AAS users, and four additional studies provided data from the United Kingdom,²⁴ Australia,^{25,26} and an international Internet cohort,²⁷ respectively (Table 1). Through the courtesy of the authors, we obtained raw data from all five American studies and three of the overseas studies.^{21,24,26} The estimated mean cumulative proportion of individuals who had initiated AAS use as of each year of age proved very consistent across the American studies (see Figure 1; for full numerical data, see Supplemental Table 1 in Supplemental Materials). Moreover, mean data from the three overseas studies fell within the 95% confidence intervals for the American studies at virtually all age points, as did the more limited published findings from the two studies for which we lacked raw data^{27,28} – suggesting that age of onset of AAS use is quite uniform around the world.

Combining American age-of-onset data with American census data, we estimated that the number of lifetimes of risk for AAS use among Americans age 13–50 was 108.5 million,

with a 95% confidence interval of 103.6–113.5 million (for details, see equation (3) in the Supplemental Materials).

American youth-survey data

1. High-school surveys—Two large surveys, the biennial Centers for Disease Control (CDC) Youth Risk Behavioral Surveillance reports, and the annual Monitoring the Future (MTF) surveys, have estimated the lifetime prevalence of AAS use among 12th graders as 2.3%–4.9% and 1.8%–4.0%, respectively, in serial surveys from 1991 to the present. Smaller American high-school studies have produced similar or even higher estimates.⁸ Despite peaks and valleys, the average lifetime prevalence of high-school AAS use has remained fairly stable over the last two decades, with no overall secular trend upwards or downwards.^{15,17}

Given the age distribution of American 12th-graders,²⁹ it follows that their ultimate lifetime prevalence of AAS use should be about 6.7 times that seen in 12th grade (as determined by equation (1) in the Supplemental Materials). Therefore, taking at face value the CDC and MTF figures from even the lowest survey years, one would predict that 12–15% of Americans eventually initiate AAS use. But this estimate is patently too high, almost certainly because teenagers frequently generate false-positive responses to the “steroid” question, as explained above. In a detailed examination of these data,⁸ we have proposed that after excluding false-positives, the true lifetime prevalence of high-school AAS use might be only 0.1% for girls and 1.0% for boys. But even assuming these much lower figures, our mathematical models would still predict that 4.0 million Americans in the current population have used AAS.

2. Young-adult surveys—MTF data indicate that the lifetime prevalence of AAS use in young adults age 19–28, for both genders combined, has been quite stable from 1989 to 2011, ranging between 1.1% and 1.9%, with a mean of 1.58%.¹⁶ Assuming equal numbers of respondents at each age from 19 to 28 in these surveys, one obtains a lifetime prevalence estimate of 3.1 million Americans.

3. College-student surveys—MTF college-student data from 1989–2011 show a 1.17% mean lifetime prevalence of AAS use (albeit with larger year-to-year fluctuations, likely due to smaller sample size).¹⁶ These data were restricted to college students 1–4 years beyond high school, and thus mostly age 19–22, with the age distribution shifted slightly leftward, since the proportion of an age group in college declines steadily with number of years beyond high school. Ignoring this shift, and assuming equal numbers of respondents at each age (thus generating a lower estimate), it would follow that 3.7 million Americans have used AAS.

Another study surveyed AAS use in students at 119 American four-year colleges on four occasions from 1993 to 2001, yielding a mean reported lifetime prevalence of AAS use of 0.96%.¹⁸ Importantly, the 2001 survey question provided examples of actual illicit AAS as follows: “Anabolic steroids (either injections, like Depo-testosterone, or Durabolin- or pills, like Anadrol, Dianabol, or Winstrol).” This question likely minimized the risk of false-positive responses, since respondents were cued with the names of genuine illicit AAS. The

reported lifetime prevalence in 2001 was 1.05%. Using the age distribution of respondents from the the 2001 study codebook,³⁰ (an approximate method, since it was applied to all four study years and neglected sampling weights), we obtained an estimate of 2.9 million American AAS users.

4. The National Household Survey—The 1994-B NHS estimated that about 1.1 million Americans (from a population of 260 million at that time) had used AAS. However, about 85% of lifetime AAS users in this survey were age 35 or less – reflecting the fact that widespread AAS use had first emerged only 10–15 years earlier. Since 1994, the NHS has not assessed lifetime AAS, but as noted above, the incidence of new-onset AAS use has remained quite stable throughout subsequent years. Thus in 2013, more than 30 years after the emergence of widespread AAS use, the lifetime prevalence in the United States should now have reached 2–3 times that in 1994. Moreover, the American population is now 1.2 times that in 1994. Therefore, projecting the NHS data forward to 2013, one would obtain an estimate of the contemporary lifetime prevalence of AAS use roughly congruent with the estimates of 2.9–4.0 million generated by the more formal methods above.

Prevalence of AAS dependence

We found nine published studies^{23,25,31–37} plus one study in progress (Pope et al., unpublished observations) that used criteria adapted from DSM-III-R or DSM-IV^{38–40} to diagnose cases of AAS dependence among 1247 AAS users collectively (Table 2). These studies generally recruited participants from gymnasiums^{23,25,31,32,34,5,37} or Internet bodybuilding and fitness sites.^{33,36} Since virtually all AAS users lift weights,¹ the study samples were therefore likely representative of the overall population of AAS users. Also, the findings seemed unlikely to be seriously biased towards cases of AAS dependence, because the studies either 1) recruited weightlifters generically without regard to history of AAS use^{23,32,33,37} or 2) recruited AAS users, but without regard to duration or extent of AAS use.^{25,31,35,36} Four studies assessed lifetime AAS dependence among lifetime AAS users, while six appeared to assess current AAS dependence among current users – but both groups of studies yielded a similar range of estimates (see Table). The mean (95% confidence interval) prevalence of AAS dependence across all studies was 32.5% (25.4%, 39.7%), with a median of 29.5%. Restricting to the six American studies, the mean was 35.0% (24.0%, 46.0%) and the median was 34.6%.

In conclusion, assuming that some 30% of AAS users develop AAS dependence, and that 2.9–4.0 million Americans have used AAS, it follows that possibly 1 million Americans may have experienced AAS dependence.

Gender ratio of AAS users

What is the ratio of male to female AAS users? A superficial examination of high-school surveys might suggest that AAS use is common in girls, with a male-female ratio of only about 2:1 in some studies.^{1,8,15} However, as detailed in our review cited earlier,⁸ most of these female cases are likely false-positives due to misinterpretation of the “steroid” question. Indeed, we are unaware of any published study that has presented even a single teenage female AAS user evaluated in person.

Turning to adult women, we have located five studies since 2000 that recruited AAS users without regard to gender^{27,28,41–43} (Table 3). Across these studies, the mean (95% CI) proportion of female users, calculated using a random effects model,¹⁹ was 1.8% (0.8%, 2.7%) – a male/female ratio of about 50 to 1. The male/female ratio for lifetime AAS use among young adults in the MTF study¹⁶ was 15 to 1 and in the 2001 college-student study of McCabe and colleagues¹⁸ it was 8 to 1. Looking at the narrower category of AAS dependence (see Table 2), only 1 (0.5%) of the 203 American cases of AAS dependence and only 2 (0.6%) of 363 cases worldwide occurred in women. The rarity of female AAS use and dependence is hardly surprising, since few women aspire to extreme muscularity, and women are also vulnerable to the virilizing effects of AAS.^{41,44} Thus, from a simple numerical standpoint, the public health threat from AAS use is largely concentrated in men.

Race/ethnicity of AAS users

Data on the race/ethnicity of American AAS users are limited. None of the national young-adult or college-student studies reviewed above provides a breakdown of AAS users by race/ethnicity. However, both the CDC and MTF high-school surveys report the percentage of white, African-American, and Hispanic students answering “yes” to the “steroid” question. Although these high-school data are vulnerable to false-positive responses, it seems fair to assume that the propensity to false-positives is similar across the three racial/ethnic categories, thus permitting a rough comparison across these groups. In MTF data for past-year “steroid” use among 12th-graders, the mean reported prevalence for 1990–2011 was 1.3% for African-Americans, 1.6% for Whites, and 1.9% for Hispanics. In recent years (2006–2011), however, these differences seem to have largely disappeared (African-American, 1.6%; White, 1.5%; Hispanic, 1.6%). In the CDC data, the mean lifetime reported prevalence of “steroid” use among all high-school students from 1993–2011 was 2.5% for African-Americans, 3.9% for Whites, and 4.4% for Hispanics. By contrast the 1994 National Household Survey found a slightly higher lifetime prevalence of AAS use in African-American versus White respondents (0.61% versus 0.50%), and a lower prevalence of AAS in Hispanic versus non-Hispanic respondents (0.46% versus 0.53%). Overall, therefore, there does not appear to be a consistent large difference among racial/ethnic groups in prevalence of AAS use.

DISCUSSION

The United States likely possesses more AAS users, and particularly more older users, than any other country, but unfortunately lacks recent general-population surveys of the lifetime prevalence of AAS use. To develop a best estimate of the lifetime prevalence of AAS use in the United States, we determined the distribution of age of onset of AAS use and applied these findings to four bodies of serial survey data from younger Americans. Our analyses suggested that 2.9–4.0 million Americans may have used AAS, with possibly one million of these having experienced AAS dependence.

Given these substantial numbers, why is AAS use and dependence not more widely recognized and more extensively studied? There are several likely explanations. First, AAS use usually starts in the 20s, when users are no longer being observed by parents or high-

school teachers. Second, public attention remains focused on AAS use in athletes, whereas the great majority of users are not competitive athletes.^{27,45} Third, AAS users are rarely candid with physicians. In one study, for example, 56% of AAS users reported that they had never disclosed their AAS use to any doctor that they had seen.⁴⁶ Fourth, physicians rarely probe for AAS use when obtaining a history,^{46,47} thus missing opportunities to establish an association between AAS use and secondary pathology such as cardiomyopathy, atherosclerotic disease, neuroendocrine abnormalities, and psychiatric disorders. Fifth, emergency-room surveillance⁴⁸ fails to detect AAS users, since AAS rarely precipitate acute emergencies such as those seen with overdoses of ordinary drugs. Sixth, widespread AAS use did not emerge until the 1980s, and thus most AAS users are still too young to have developed sufficient medical problems to attract clinical attention. Collectively, these factors have likely combined to keep AAS dependence largely unnoticed.

Our findings are subject to various limitations. First, our estimated distribution for age of onset of AAS use, based on nine pooled studies, is vulnerable to selection bias in the underlying studies. However, the consistency of findings across these studies argues against a major bias in either direction. Second, our calculations utilized four youth-survey datasets that likely included false-positive responses, potentially inflating estimates. Although we introduced various conservative analytic assumptions to compensate for false-positives, this possible source of bias cannot be excluded. Notably, however, when analyzing a college-student survey that specifically named representative examples of AAS on the questionnaire, thus minimizing the risk of false-positives,¹⁸ we still obtained an estimate of 2.9 million lifetime users in the general American population. Third, our estimate of the lifetime prevalence of AAS dependence, based on 10 pooled studies of AAS users, is again vulnerable to bias in the underlying studies. As discussed above, however, analysis of these studies suggests that they probably secured representative samples of AAS users, spanning the full range of AAS exposure.

In short, each component of the estimation process is potentially vulnerable to bias, and an error in one component might be magnified through the multiplier process used in our mathematical models. However, it appears implausible that a severe bias has affected all estimation components in the same direction. It is also reassuring that the various prevalence estimates, derived from different indicator populations, converged fairly closely. Thus, pending more sophisticated survey data, the estimates developed here appear reasonable for provisional purposes.

If our conclusions are valid, and AAS use and dependence are indeed prevalent and largely undetected in the American population, it would seem important to watch for possible public health consequences in the steadily aging population of current and former AAS users. Expanded research and intervention today may help to avert some of these consequences in the future.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. Estimated mean cumulative percentage of anabolic-androgenic steroid (AAS) users who have initiated use by a given year of age, based on five American studies collectively evaluating 2549 AAS users.

Table 1

Studies Assessing Age of Onset of AAS Use

Study	Method	Location	AAS Users ^a	Current Age	Age at 1st AAS Use
Copeland et al., 2000	Personal interview	Australia	94M, 6F	18–50	14–46
Kanayama et al., 2003	Personal interview	USA	48M	18–65	13–37
Parkinson & Evans, 2006	Internet survey	International	494M, 6F	16–62	14–58
Cohen et al., 2007	Internet survey	USA	1788M	18–76	14–68
Larance et al., 2008	Personal interview	Australia	60M	17–59	15–58
Ip et al., 2011: American respondents	Internet survey	USA	375M, 5F	16–73	13–69
Ip et al., 2011: Non-American respondents	Internet survey	Non-USA	127M, 7F	16–73	13–51
Pope et al., 2012	Personal interview	USA	102M	18–40	15–37
Kanayama et al., 2013	Personal interview	UK	31M	29–55	16–41
Pope et al., ongoing	Personal interview	USA	75M	34–55	15–49

^a Represents the number of AAS users for whom age of onset was ascertained, after cases with missing data were deleted.

Table 2

Prevalence of AAS dependence in studies of AAS users

Study	Location	AAS users	<u>Dependent users^a</u>	
			N	%
Brower et al., 1991	USA	49M	28	57.1
Gridley & Hanrahan, 1994	Australia	21M	12	57.1
Pope & Katz, 1994	USA	88M	22	25.0
Malone et al., 1995	USA	71M, 6F	10M, 1F	14.3
Midgley et al., 1999	UK	50M	13	26.0
Copeland et al., 2000	Australia	94M, 6F	22M, 1 F	23.0
Perry et al., 2005	USA	206M	68	33.0
Pope et al., 2012	USA	102M	37	36.3
Ip et al., 2012	International	479M	112	23.4
Pope et al., ongoing	USA	75M	37	49.3

^aThe study of Malone et al. and the three studies of Pope et al. assessed lifetime history of AAS dependence in individuals with lifetime AAS use; the other six studies appeared to assess only current AAS dependence among current AAS users.

Table 3

Gender ratios in recent studies of AAS users that assessed both men and women

Study	Method	Location	Study Population	AAS Users		Percent female
				Male	Female	
Copeland et al., 2000	Personal interview	New South Wales, Australia	100 AAS users age 18–50	94	6	6.0
Kanayama et al., 2001	Anonymous questionnaire	Massachusetts, USA	501 gymnasium clients	18	0	0.0
Parkinson & Evans, 2006	Internet survey	International	500 current or past AAS users	494	6	1.2
Ip et al., 2011	Internet survey	International	518 current or past AAS users	506	12	2.3
Leifmann et al., 2011	Anonymous questionnaire	Stockholm region, Sweden	1752 gymnasium clients	45	1	2.2