Anabolic Steroid Use in Adolescents: Identification of Those at Risk and Strategies for Prevention

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Anabolic Steroid Use in Adolescents: Identification of Those at Risk and Strategies for Prevention

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Abstract: Success in sports is often defined by winning, which drives athletes to use performance-enhancing drugs (PEDs) to gain an advantage over opponents. Over the past 20 years, use of PEDs by Olympic and professional athletes has led to public discussion regarding potential negative health effects and ethical implications of their use. Unfortunately, PEDs are not isolated to professional athletes, as PED use in adolescents has increased dramatically. Many professional organizations, including the American Academy of Orthopaedic Surgeons (AAOS), have taken a stance against PED use in sports. The AAOS believes neither anabolic steroids nor their precursors should be used to enhance performance or appearance, and that these substances should be banned in all sports programs. Pediatricians and orthopedists are often the first physicians to see these young athletes. It is critical for these physicians to recognize the significance of the problem, have the knowledge to inform adolescents, dissuade them from future use, and provide viable alternatives for meeting performance goals.

Keywords: adolescents; performance-enhancing drugs; anabolic steroids; athletes

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Introduction

Sports participation is an incredibly popular activity worldwide. Winning often defines success, which can motivate athletes to use performance-enhancing drugs (PEDs) in hopes of gaining an advantage over their opponents. Over the past 20 years, use of PEDs by Olympic and professional athletes in the United States has prompted heavily publicized discussions of negative health effects and ethical implications of their use.[1,2] It is estimated that > 1 million people in the United States use anabolic-androgenic steroids (AAS), with associated costs of > $100 million per year.[3] A 1997 Sports Illustrated poll revealed that 98% of current and aspiring Olympic athletes would take a banned PED if it guaranteed both winning their athletic event and no suspension for drug use. The poll also revealed that 50% would take the same substance if it would enhance their ability to win every competition for the next 5 years, but result in death.[4] This "win-at-all-costs" mentality has supplanted traditional methods of physical training and proper nutrition. Although there is a long history of PED use among professional and Olympic athletes, these substances are no longer limited to elite athletes. There has been a significant increase in the use of AAS, steroid precursors, creatine, and nutritional supplements among adolescent athletes and nonathletes for both athletic and nonathletic purposes.[1]

Performance-enhancing drugs are defined by the American Academy of Pediatrics (AAP) as any substance taken in nonpharmacologic doses specifically for the purpose of improving sports performance through increased power, strength, speed, or endurance (ergogenic), or altered body weight or composition.[5] Performance-enhancing drugs include AAS, hormone precursors, stimulants, human growth hormone (HGH), agents used to increase oxygen-carrying capacity, agents used for weight control and weight gain, and any substance known to limit detectability of other known PEDs. Nutritional supplements taken at supraphysiologic doses are also included in this category[5] (Table 1). Although there are numerous substances used to increase one's performance both on and off the playing field, this article focuses specifically on AAS use in adolescents.

Anabolic-Androgenic Steroids

Anabolic-androgenic steroids are synthetic derivatives of testosterone that are used for increasing fat-free muscle mass and strength.[1] Steroid use is often seen in athletes participating in football, weightlifting,

Table 1. Potential Benefits and Side Effects of Selected Performance Enhancing Drugs[4,22,23]

Substance	Potential Benefits	Potential Side Effects
Steroid hormone precursors (eg, androstenedione, dehydroepiandrosterone)	None proven	Increased estrogen levels in boys Possible androgenic effects
Creatine	Increased strength Weight gain Improved performance in short anaerobic efforts	Muscle cramps Dehydration Gastrointestinal symptoms Potential risk for renal toxicity
Stimulants (eg, caffeine, ephedra)	Increased endurance	Anxiety Inability to focus Insomnia Irritability
Human growth hormone	No proven effects on performance Decreased subcutaneous fat	Hypertension Coarsening facial features Impaired glucose tolerance Cardiovascular disease
Erythropoietin	Increased endurance	Thromboembolic events Ischemic events Hyperkalemia
Diuretics	Weight loss Enhanced muscle definition	Dehydration Electrolyte imbalances
Nutritional supplements	None proven	Unregulated substances Potential side effects vary

baseball, and basketball to improve athletic performance and enhance strength, whereas use by nonathletes aims to improve appearance and build self-esteem.[6–8] Anabolic-androgenic steroids act on the musculoskeletal system to influence lean body mass, muscle size and strength, and protein metabolism.[9–13] Manufacturers modify the chemical structure of testosterone to maximize anabolic effects by delaying metabolism.[14] Transported into the cell nucleus, steroids bind DNA, increasing RNA transcription, which enhances contractile and structural protein synthesis. Binding androgen receptors promotes a positive nitrogen balance in muscle and produces an anabolic state,[15,16] leading to muscle hypertrophy and increased muscle strength.[11,12] Exercise stimulates increased glucocorticoid release, which promotes breakdown of muscle glycogen for energy.[15,17] Anabolic-androgenic steroids have an anticatabolic effect. Once steroids saturate androgen receptors, the remaining exogenous steroids competitively inhibit binding of catabolic glucocorticoids, thereby preserving muscle mass. By displacing cortisol from its receptors, steroids can prevent tissue breakdown, allowing athletes to exercise more frequently and at a higher intensity, with less muscle breakdown and soreness after strenuous training. Thus, athletes maintain more of their strength and conditioning gains.[18] Additionally, steroids create a euphoric state and decrease fatigue, which enables prolongation of training sessions.[2,15]

Pattern of Use

Anabolic-androgenic steroids are available in both oral and injectable preparations, and are grouped into 3 main classes.[19] Class I is composed of testosterone esters (eg, testosterone propionate), which are injectable substances. Class II agents include nortestosterone derivatives (eg, nandrolone decanoate). Both Class I and II substances exert their effects at androgen and estrogen receptors via aromatization to estriol.[20] Class III substances (those alkylated at C17) include oxymetholone, available in an oral preparation, as well as methandrostenolone and stanozolol, which are available in both oral and injectable preparations. Alkylation of these compounds slows the hepatic metabolism.[21] Athletes will often take a combination of oral and injectable medications for 6- to 12-week cycles. Injectable drugs are favored because they are less hepatotoxic; however, they can be detected months after use. Oral steroids are eliminated over a period of days and are preferred when drug testing is anticipated.[2,15,22]

The simultaneous use of multiple steroid preparations is referred to as "stacking" and is a common practice among AAS users. These users will often "pyramid" their drug regimen, which involves increasing the dose of a drug throughout a cycle. This pattern may lead to doses 10 to 40 times greater than those used for medical indications. The efficacy of "stacking" and "pyramiding" has yet to be proven; however, these practices maximize steroid receptor binding and minimize toxic side effects.[2,15,22,23] Tamoxifen and anti-aromatase drugs are used to prevent or decrease gynecomastia by limiting estrogenic effects and metabolism of excess testosterone derivatives to estradiol.[24]

Clinical Uses of AAS

Steroids have been used in clinical practice since the 1940s to treat trauma, burns, extensive surgery, radiation therapy, and chronic debilitating illnesses.[20,25,26] Anemia was historically treated with steroids before the advent of bone marrow transplantation and erythropoietin.[2] Steroids can also be used for short stature in Turner's syndrome or constitutional growth and puberty delay.[2] Hereditary angioedema, palliation therapy in advanced breast cancer, and replacement therapy in hypogonadal men are among other conditions treated with steroids.[18] Since 1985, the clinical use of steroids has increased 400%, mostly because of the management of acquired immune deficiency syndrome (AIDS)-associated wasting syndrome.[2]

Side Effects

Despite routine steroid use in clinical practice, their desired effect on specific areas of the body portends potential adverse effects on several organ systems (Table 2). Anabolic-androgenic steroids can lead to transient elevations in liver enzymes (aspartate aminotransferase [AST], alanine aminotransferase [ALT], and lactate dehydrogenase [LDH]) and subsequent liver toxicity. Liver function tests peak within 2 to 3 weeks of consumption and return to baseline within several weeks of discontinuation.[27] Aspartate aminotransferase, ALT, and LDH are present in both the liver and skeletal muscle. A study by Pettersson et al[28] in 2008 illustrated that intense muscular exercise can cause an asymptomatic elevation in routine liver function tests due to muscle damage alone. Therefore, it may be more useful to measure γ-glutamyl transaminase in patients suspected of using AAS because this enzyme is found exclusively in the liver.[28] Hepatocellular adenomas are associated with high-dose steroids, long periods of administration, and in steroid users with predisposing medical conditions,[17,27,29] and must be identified early because of the potential for malignant transformation.[30]

Table 2. Adverse Effects of Anabolic-Androgenic Steroids[4,19]

System	Effects
Cardiovascular	Increased total cholesterol Increased low-density lipoprotein Decreased high-density lipoprotein Hypertension Myocardial ischemia Cerebrovascular accidents
Male reproductive	Abnormal spermatogenesis Impotence Testicular atrophy Gynecomastia Priapism Prostatic hypertrophy Prostate cancer
Female reproductive	Menstrual irregularities Hirsutism Clitoromegaly (irreversible) Deepening voice (irreversible) Male-pattern baldness Uterine atrophy Breast atrophy
Musculoskeletal	Premature physeal arrest Increased risk of tendon or muscle injury
Liver	Elevated liver function tests Hepatocellular carcinoma Hepatoadenoma
Skin	Acne Striae
Psychological	Mood swings Aggressive behavior Depression Addiction Withdrawal

Anabolic-androgenic steroids affect the serum lipid profile, leading to increased total cholesterol and decreased high-density lipoprotein. Anabolic-androgenic steroids have also been associated with, and believed to cause, thrombotic events, including stroke and myocardial infarction.[30,31] Long-term AAS use may lead to cardiac dysfunction severe enough to cause heart failure.[32] Anabolic-androgenic steroid abuse also has been associated with development of focal segmental glomerulosclerosis and proteinuria.[33]

In men, AAS provide feedback inhibition of luteinizing hormone and follicle-stimulating hormone, which decreases endogenous testosterone production and subsequently leads to decreased spermatogenesis and testicular atrophy, a condition known as anabolic steroid-induced hypogonadism.[34] Gynecomastia also occurs frequently in men taking AAS because of the peripheral conversion of androgens to estradiol and estrone. Women taking AAS often suffer masculinizing effects, including hirsutism, acne, deepening of the voice, male-pattern baldness, and clitoral hypertrophy. These androgenic effects may be irreversible.[15,22,30]

Anabolic-androgenic steroid use in adolescents may lead to premature physeal closure and ultimately decreased adult height.[15,35] Experimental evidence has demonstrated that steroid use combined with intense exercise can cause structural and biomechanical alterations of tendons, leading to rupture. Collagen fibril alignment is disorganized, and when muscle strength is increased with steroids, tendons becomes stiffer, absorb less energy, and are more likely to fail during physical activity.[36,37]

Men and women using AAS experience mental and behavioral changes, including irritability, aggressiveness, euphoria, depression, mood swings, altered libido, and psychosis.[15] Pope and Katz[38] studied weightlifters using steroids and found that 23% of steroid users experienced major mood changes of mania, hypomania, or major depression, as well as aggressive behavior resulting in fights, domestic disturbances, assaults, and arrests. Data from the National Household Survey on Drug Abuse showed a strong association between steroid use and self-acknowledged acts of violence against people and crimes against property.[39] Behavioral effects are variable and are related to the type and dose of steroids. There is the potential for dependence on steroids. In 1 series, 50% of steroid users met the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* (DSM-IV) definition for dependence or abuse of steroids.[40,41] Discontinuing steroid use may cause an acute anabolic steroid withdrawal, with symptoms of noradrenergic hyperactivity, such as anxiety, irritability, insomnia, hot flashes, sweats, chills, anorexia, myalgias, nausea, vomiting, piloerection, tachycardia, and hypertension.[15,42]

AAS Use Among Adolescents

The AAP strongly condemns the use of PEDs and endorses efforts to eliminate their use among children and adolescents. The policy statement issued by the AAP conveys 3 main points: 1) the intentional use of any substance for performance enhancement is unfair and, therefore, morally and ethically indefensible; 2) the use of any substance for the purpose of enhancing sports performance, including over-the-counter supplements, the composition and quality of which are not under federal regulation, may pose significant health risk to the young person; and 3) the use and promotion of PEDs tend to devalue the principles of a balanced diet, good coaching, and sound physical training.[5] A 2007 youth athlete survey reported that 17% of boys and 10% of girls disagreed with the statement "No athlete should use PEDs because it's unhealthy."[43] Similarly, 15% of boys and 11% of girls disagreed with the statement "No athlete should use PEDs because it's cheating."[43] Unfortunately, as perceived by adolescent athletes, the potential for success in sports often outweighs the prospects for serious medical complications from the use of PEDs.[5]

The first published report of AAS use in an adolescent was in 1959 by a high school football player,[44] and the rate of use continues to increase. Self-reported adolescent steroid use has been as high as 11% for males and 2.5% for females, with a significant portion composed of athletes in nonschool sports and nonathletes.[15] Buckley et al[6] surveyed 3403 male twelfth grade students from US high schools and found that 6.6% of the participants used or had used AAS. In a study of 6903 high school students in Denver, CO, Tanner et al[45] reported overall steroid use of 3% (greater reported use in boys compared with girls, 4% and 1%, respectively). In a survey of 4722 students from 62 elementary schools, Scott et al[8] found that 3% reported steroid use in the past 30 days, with boys using more than girls (5% and 1%, respectively). Faigenbaum et al[46] reported on steroid use among 965 middle school students aged between 9 and 13 years, and found that nearly 3% of children used steroids. In 1999, Stilger and Yesalis[47] surveyed 1325 varsity football players from 27 high schools in Indiana and reported a user rate of 6%.

This trend is mirrored nationally. The Monitoring the Future Study[48] is examining the largest nationwide cohort, consisting of nearly 50 000 students. As of 2004, this ongoing study indicated 1.3%, 2.3%, and 3.3% annual prevalence rates of male steroid users in eighth, tenth, and twelfth grades, respectively. It also revealed that girls in twelfth grade had a 1.7% user rate.[48] The Youth Risk and Behavior Surveillance System evaluated the presence of AAS use among ninth to twelfth graders from 1991 to 2005.[49] This study surveyed between 10 904 and 16 262 students from across the United States annually, revealing prevalence rates for lifetime use of AAS ranged from 2.2% in 1993 to 6.1% in 2003 (boys > girls). Similarly, the National Household Survey on Drug Abuse[50] surveyed between 4678 and 8005 adolescents aged 12 to 17 years nationwide from 1991 to 1994, and assessed lifetime use of AAS. The study found that prevalence rates of lifetime use ranged from 0.2% in 1993 to 0.6% in 1991, with rates consistently higher among boys than girls. The lower prevalence compared with the previous 2 studies is likely due to a broader age range of the sample group studied.

Studies have also shown that steroid use among adolescents is significantly associated with previous use of cocaine, injectable drugs, alcohol, marijuana, shared needles, and smokeless tobacco.[15,51] In 2007, Elliot et al[52] reviewed data from the 2003 Youth Risk and Behavior Surveillance System to examine the characteristics of girls reporting anabolic steroid use. They found that adolescent girls reporting steroid use had a significantly increased rate of using cigarettes, alcohol, and marijuana, and were more likely to report a history of being pregnant.

The contradictory nature of the results reported in these studies may be readily explained by the ambiguity of questions related to steroid use. Often, these questions do not specify AAS use as opposed to corticosteroids. A study by Kanayama et al[53] in 2007 reviewed 4 large national surveys and several smaller surveys and found that the imprecise nature of questions on steroids has led to a significantly overestimated lifetime prevalence of AAS among teenage girls. Their analysis revealed a lifetime prevalence of 0.5% and perhaps even as low as 0.1% among teenage girls.[53]

Identification of Adolescents Using AAS

Adolescents using AAS are more likely to be male athletes involved in sports that demand a high level of strength, power, size, and speed. However, 30% to 40% of adolescent steroid users do not participate in school-sponsored sports, and are instead focused on body image.[1] Knowing or accepting teammates, competitors, or other athletes who use these substances, or believing that use is widespread may increase the likelihood of using.[46] Adolescents who sense pressure from parents, coaches, or teammates to succeed in athletics and who believe their self-worth is defined by sports performance are at high risk of using AAS.[23]

Physicians may notice gains in lean body mass and muscle bulk and behavioral changes (eg, increased aggressiveness) in adolescents using AAS. Unfortunately, most young people who use AAS are not easily identifiable. All adolescents should be asked about the use of AAS while assessing for other high-risk behaviors as part of every adolescent health maintenance visit and preparticipation sports physical. On admission of steroid use, patients should be provided with unbiased medical information on the risks, benefits, and known adverse effects associated with AAS. Physicians should explore the patient's motivation for using steroids and provide counseling on safer alternatives for meeting performance goals. It is important to understand the adolescent's perspective and have a balanced discussion on the risks and benefits of steroid use rather than employ scare tactics.[5] Encouraging an open line of communication will make the adolescent less likely to withhold important information that may adversely affect his or her health. In general, adolescents are more inclined to share sensitive information with the physician in the absence of their parents. However, parents should receive general information about outward physical and behavioral changes associated with AAS use and be encouraged to contact the physician with any concerns. A strong relationship between the physician and parents provides the best means of effectively caring for adolescents and minimizing the potential for AAS use.[5,15,23]

Safe Alternatives for Meeting Performance Goals

Strength training is a popular and rapidly evolving method of enhancing athletic performance.[54] It was initially limited to sports that were thought to require strength for optimal performance, but it is now included in nearly all sports activities. Strength training can be used to improve sports performance and prevent injuries, rehabilitate injuries, and/or enhance long-term health. It has a beneficial effect on cardiovascular fitness, body composition, bone mineral density, blood lipid profiles, and mental health.[55]

Although adult athletes often participate in some form of strength training to enhance performance, endurance, and decrease the risk of injury, the role of strength training in children has been a topic of considerable debate[54,56,57] because of 3 misconceptions. First, prepubescent athletes cannot benefit from strength training because of insufficient circulating levels of androgens.[58] Current evidence indicates that a properly planned and supervised training program will promote strength gain in young athletes.[59] Second, athletes participating in strength training lose both flexibility and range of motion necessary for optimal performance in their sport.[59] Third, strength training is dangerous and exposes young athletes to an unnecessary risk of injury.[59] Studies reveal injuries in children from strength training range from 7% to 40%, similar to those associated with other sports or recreational activities.[54] Of these injuries, 75% were strains,[59–61] which commonly occur on home equipment where adolescents are unsupervised.[55] Resistance training leads to significant gains in strength in the prepubescent child, not related to muscle hypertrophy, but rather to neural adaptations, motor coordination, and intrinsic muscular adaptations.[62,63]

The AAP issued a policy statement on strength training in adolescents, suggesting it as an adjunct to exercise and sports participation. For gains in strength, workouts with proper technique and strict supervision should be 20 to 30 minutes long, 2 to 3 times per week, and continue to add weight or repetitions as strength improves.[55] Although studies have not demonstrated enhanced performance with strength training, anecdotal evidence supports its efficacy.

Prevention of AAS Use in Adolescents

Although open dialogue between the physician and adolescent patient regarding AAS use is beneficial, drug testing and educational programs remain the most commonly employed modalities for prevention of AAS use in adolescents. Drug testing is largely punitive, with positive tests imposing significant penalties, including loss of playing privileges, removal of rewards or championships from the entire team, loss of scholarships, or restrictions on future regular season or postseason play. These are intended to be deterrents, but have little effect on most children and adolescents.[5]

Drug and alcohol testing in high school athletes has been identified as a possible way to prevent, identify, and treat substance use.[64–67] In 1995, the US Supreme Court legalized drug testing among adolescent athletes engaged in school-sponsored sports,[68] expanding in 2002 to students involved in all extracurricular school-based activities.[69] In 2003, the National Federation of State High School Associations indicated that 13% of schools tested athletes, 29% of which tested for steroids. The limited testing is due to financial constraints, with each test costing $120.[2,70] The June 2008 issue of *AAOS Now*[71] highlighted key features of high school steroid screening programs in New Jersey, Texas, Illinois, and Florida. These programs are in their infancy, test only a small sample of high school athletes, and mandate suspensions, ranging from 30 days to 1 year, for a positive result.[71]

The American Academy of Orthopaedic Surgeons (AAOS) takes a strong stand against the use of PEDs to improve athletic performance. The Code of Medical Ethics and Professionalism for Orthopaedic Surgeons states that "it is unethical to prescribe controlled substances when they are not medically indicated. It is also unethical to prescribe substances for the sole purpose of enhancing athletic performance."[72] The AAOS believes that anabolic steroids and their precursors should not be used to enhance performance or appearance and should be banned from all sports programs. To deter and detect drug use, the AAOS suggests that aggressive drug testing programs be implemented, and harsh penalties be imposed for positive results.[72]

There are numerous methods to avoid a positive result. Titrating doses with newer transdermal delivery systems of testosterone, or discontinuation of use before a scheduled test can maintain levels below testing threshold.[73,74] Urine drug testing is limited because a negative test does not mean that a person is not using drugs, rather that the test did not detect a specific drug. Additionally, diuretics have been used to decrease urinary concentration of prohibited drugs.[75] Unfortunately, the prohibitive cost of testing and deficiencies associated with detection make it unlikely that widespread testing of adolescents and children will be effective or practical.[5,71]

Educational programs address social, media, and peer influences that perpetuate adolescent steroid use as a means of becoming a successful athlete. Physician dissemination of accurate information to parents, coaches, and school administrators is essential toward creating an intervention program.[2] The Adolescent Training and Learning to Avoid Steroids (ATLAS) program serves as the model for deterring steroid use among high school athletes. ATLAS set out with a goal of reducing the risk factors that encourage the use of AAS and other drugs by using the athletic team as a means of deterring drug use, while at the same time promoting healthy nutrition and exercise as alternatives. The program consisted of ten 45-minute interactive classroom sessions and 3 exercise sessions regarding sports nutrition, exercise alternatives, effects of substance abuse in sports, drug refusal role-playing, and creation of health promotion messages. The sessions were delivered over a 7-week period by coaches and athlete team leaders.[3] Combining drug education with personal skills, athletes learned to resist social influences promoting the use of steroids. Compared with a cohort receiving only brochures with similar information, athletes in the intervention group had a better understanding of the consequences of steroid use, were more skeptical about steroid promotion, and had improved drug refusal skills.[22,76,77]

Similarly, Athletes Targeting Healthy Exercise and Nutrition (ATHENA) was a school-based, team-centered prevention program for female athletes on sports, dance, and cheer teams.[78] Consisting of eight 45-minute sessions integrated into the athlete's sport training activities, it aimed to reduce eating disorders and the use of diet pills and other supplements, while promoting healthy nutrition and exercise. The intervention resulted in a significant improvement in healthy activities, including a reduction in the use of diet pills, amphetamines, AAS, supplements, and alcohol.[78]

Implementation of educational programs requires a significant amount of effort; however, ATLAS and ATHENA have proven this effort to be worthwhile, as these programs were extremely effective in deterring use of AAS and other harmful substances. Incorporating these programs into the adolescent's daily activities is more likely to be effective at deterring AAS use than urine drug testing, which is costly and associated with numerous deficiencies in detection.

Conclusion

Physicians treating young athletes must search for signs and symptoms of AAS use and intervene. Communication with athletes regarding substance use to enhance athletic performance is critical. It is important to be clear that the aspiration is to help young athletes, not report them to authorities.[79] Physicians caring for these athletes should be educated about the substances abused, as well as their risks and benefits. Although numerous PEDs are available, we only have substantial information on the effects and side effects of AAS. Unfortunately, there is currently no cost-effective way of identifying adolescents who use AAS. Based on a thorough review of the literature, extensive educational programs such as ATLAS or ATHENA[3,78] seem to be the most effective means of preventing steroid use among adolescents.

The increasingly competitive environment in adolescent sports requires coaches to understand the influence that AAS have on young athletes. Continued education of parents, coaches, and physicians will equip them to inform adolescents, dissuade them from future use, provide viable alternatives, and transition from a "win-at-all-costs" mentality to one of fair and honest competition.

Conflict of Interest Statement

Mary K. Mulcahey, MD, Jonathan R. Schiller, MD, and Michael J. Hulstyn, MD disclose no conflicts of interest.

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