

September 2006

Special Report

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NSCA's
**Performance
Training**
Journal

Steroids:

Special Report



National Strength and Conditioning Association

Bridging the gap between science and application

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STERIODS: Special Report

September 2006

It's a disturbing fact: strength and conditioning coaches, personal trainers, and most every practitioner involved in strength and conditioning has either dealt with the issue of steroid use or will.

Strength and conditioning professionals at all levels are looked to for expert guidance on the topic of steroids. And although these professionals work extensively with athletes on a day-to-day basis, many lack the educational tools to inform themselves, their athletes, and the public on steroids.

With the help of EAS, the National Strength and Conditioning Association is helping to educate the educators about what steroids are and are not, and help prevent athletes from ever using steroids—not through scare tactics and didactic discussion but through education and understanding.

The National Strength and Conditioning Association is committed to promoting athletic performance based on proper training methods and fair play, and in so, denounces the use of Anabolic-Androgenic Steroids for the purpose of performance enhancement.

For more information on the NSCA Steroid Education Program, call 800-815-6826.



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As the worldwide authority on strength and conditioning, we support and disseminate research-based knowledge and its practical application, to improve athletic performance and fitness.

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Anabolic Steroids: Education and Awareness

Michael Barnes, MEd, CSCS,*D, NSCA-CPT,*D

There has not been a time in recent history that more attention has been brought to the use of anabolic steroids (AS). The media has covered major stories involving high profile athletes from various sports, to trafficking, to politics, to the use of steroids by girls in high schools. The statistics of use and media coverage is beyond alarming. If you participate in athletics or have been involved it is only a matter of time of when you will be confronted with this issue.

The purpose of this article is to give a general overview of a theoretical model that has been used to prevent anabolic steroid use and also propose what a grass roots model may look like.

The Steroid Challenge

One of the primary issues that arise when attempting to educate athletes on steroid use is that they typically have positive social connotations. This opposes what is seen in the use of recreational drugs like cocaine, marijuana, or ecstasy. These recreational drugs are perceived to have a self-destructive tendency associated with their use. At this same time it is often portrayed that steroids will enable an athlete to win a game, get

more muscular, or become more physically attractive all of which are typically perceived as positive in our society. So it appears to be a challenge when educating athletes to the adverse effects of anabolic steroids because of the inherent positive effects; those effects being real or otherwise.

Steroid Legislation

In January of 2004 President George W. Bush said in his State of the Union Address, *“The use of performance-enhancing drugs like steroids in baseball, football, and other sports is dangerous... I call on team owners, union representatives, coaches, and players to take the lead... get rid of steroids now.”*

Later that year, the President signed the “Anabolic Steroid Act of 2004”. The signing of this act was meant to “Amend the Controlled Substances Act to clarify the definition of anabolic steroids and to provide for research and education activities relating to steroids and steroid precursors.” The updated list of these schedule III drugs now includes androstenedione (Andro) and tetrahydrogestrinone (THG) in addition to the list of traditional anabolic steroids.

What Does Not Work

Some educational and prevention models for anabolic steroid use have been attempted in an effort to quell usage. These attempts have included:

- Scare tactics
- Didactic discussions
- Campaigns such as *“Just Say No”*
- Drug testing
- Threats

Each of these tactics has had little effect and in some cases, possibly the reverse effects the program was hoping to achieve. For instance, scare tactics and threats are often perceived by athletes as a challenge, drug testing has never been scientifically proven to work, and purely informational handouts, statistics, and lectures do not appeal to the social values of the athlete. For all of these reasons a more strategic approach is suggested.

What Does Work

Social-psychological interventions are programs that focus on improving behavior within a group (society) and how that group perceives the environment. It has been suggested that when implementing a social-psychological program that the components are age

appropriate, contain multiple years of intervention, have detailed lesson plans, teach norms of drug use, and use interactive teaching methods (4). This type of intervention strategy was used for Athletes Training and Learning to Avoid Steroids (ATLAS) program.

ATLAS is a multi-component universal intervention that focuses on risk and protective factors of anabolic steroid use. ATLAS takes advantage of the unique properties of the athletic team to deter drug use and promote healthy nutrition and exercise as alternatives to drug use in sports. ATLAS targets male adolescent athletes use of anabolic steroids, alcohol, and other drugs and sport supplements, while improving healthy nutrition and exercise practices.

Compared with controls of the ATLAS program, experimental subjects were significantly less interested in trying steroids after the intervention, were less likely to want to use AS even if their friends used them, were less likely to believe steroid use was a good idea, believed steroids were more dangerous, had better knowledge of alternatives to steroid use, had improved body image, increased their knowledge of diet supplements, and had less belief in that AS were as beneficial (1).

There are ten sessions of the program that are peer lead. They are:

- **Session 1:** Overview of the Atlas Program, describing testosterone and basic nutrition
- **Session 2:** Basic strength training and basic program design
- **Session 3:** Importance of fluids, sports menu guide

- **Session 4:** Side effects of steroids, supplement expensive and claims
- **Session 5:** Timing of snacks, benefits and risks of steroids, recreational drugs and performance
- **Session 6:** Students develop an anti-steroid campaign
- **Session 7:** Students learn negative effects of a high fat diet, students present anti-steroids campaign
- **Session 8:** Students discuss better ways to become better athletes
- **Session 9:** Students create mock newspaper article on drugs, supplements, training or nutrition in sports, students will poll female athletes about male body types
- **Session 10:** Students review key facts about steroids, nutrition and exercise, students commitment poster will be signed, squad leaders recognized

For more information on this program visit: www.ohsu.edu/hpsm/atlas.html

Initiatives of the National Strength and Conditioning Association

The National Strength and Conditioning Association has been one of the first organizations to take a stance against the use of anabolic steroids. The official position statement of the NSCA can be viewed at...

www.nsca-lift.org/Publications/posstatements.shtml#steroid.

In a joint effort between the NSCA and EAS, owned by Abbott Ross Laboratories, they will be launching a new Steroid Education and Awareness campaign that will be implemented throughout the

US. NSCA volunteers will assist at state and national conferences to help spread information as it relates to anabolic steroids usage.

There are three primary tenants of the program. They are the steroid education component, the strength and conditioning component, and the nutritional component.

- **Steroid Education:** What are anabolic steroids, how do they work, how does the body produce them, anabolic steroids history and what the research is saying about their use.
- **Strength and Conditioning:** the fundamental principals of strength and conditioning, and strategies that promote muscle growth and improve athletic performance are addressed.
- **Nutrition:** the six essential nutrients are covered, caloric balance, meal timing and reasonable supplementation are covered.

The depth of the information being presented will depend on the target audience. A professional strength and conditioning coach will need to be well prepared when speaking to high level or professional athletes because of their unique environment they train and compete in. This may differ from parents of youth athletes who could be more interested in the signs that predispose their children to anabolic steroids use.

Summary

According to some reports the use of steroids has been reported both on the rise and the decline depending on the demographic (2,3). One thing is for sure, anabolic steroid use does not appear to be going away. Athletes and organic chemist continue to push the limits and find ways to beat testing protocols and athletes at all levels are apparently willing to accept the associated risks to their bodies and legal implications. A well thought out educational strategy maybe the best approach to deter anabolic steroid use.

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Anabolic-Androgenic Steroids

G. Gregory Haff, PhD, CSCS,*D

The use of anabolic-androgenic steroids (AAS) by athletes has been widely recognized since the 1950's (29). However, the use of these drugs has been prohibited in Olympic Sports by the Medical Commission of the International Olympic Committee since 1974 and testing for anabolic-androgenic steroids has been undertaken since 1976 (30). Recently, the discovery that “designer steroids” are being conceived and used with an explicit goal of avoiding drug testing in order to improve sports performance brings a new dimension to the complex practice of regulating and monitoring drug use in sports. This concept was once the stuff of rumor (39), however, recent events suggest that unscrupulous chemists may be creating drugs faster than drug testers can create mechanisms to reliably test for them (33). In fact Handelsman (28) has suggested that new steroids, that are not on any of the current World Anti Doping Agency (WADA) lists or controlled by the United States government, are being created at a rate that out paces the ability of regulatory agencies to discover and determine the effects of these compounds. The realization and publication in the popular media that there exists a subculture of athletes that are using these synthetic compounds to improve

athletic performance appears shocking to the average individual. Often the flood of media information is sensationalized and offers non-scientifically based information. Therefore, the purpose of this brief review is to examine 1) what steroids are, 2) what steroids do, 3) what designer steroids are, and 4) other what might be on the doping horizon.

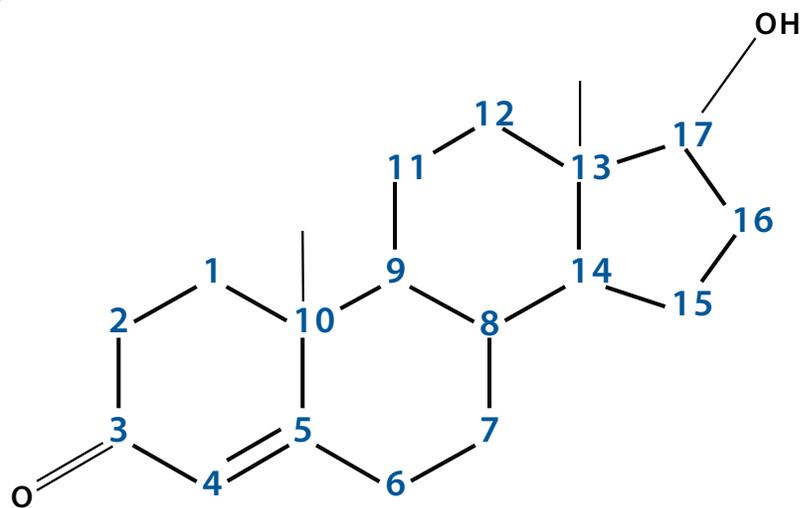
What are Anabolic-Androgenic Steroids?

Anabolic-androgenic steroids are synthetically derived compounds based upon the structure of testosterone (45) (figure 1). Testosterone is classified as a steroid hormone and is constructed from

cholesterol through a series of enzymatic steps in the Leydig cells of the testes and adrenal cortex in men, while the adrenal cortex is the primary site of synthesis in women (21). Testosterone is responsible for the development and maintenance of secondary male sexual characteristics, also known as androgenic effects, and anabolic effects which are general considered to be the promotion of muscular growth (44).

Generally, testosterone is considered to be a poor AAS because when taken orally it is rapidly degraded and only small amounts reach the systemic circulation. Additionally, when testosterone is injected, effective levels of the drug are not sustained because of rapid degradation (48). In order to maximize the effectiveness of AAS, the base chemical structure of testosterone is generally modified by 1) esterification at the 17 β -hydroxyl group, 2) alkylation at the 17 α -position, or 3) modification at either the 1, 2, 9, or 11 carbons of the ring structure of the steroid (48) (figure 2).

Figure 1. Chemical Structure of Testosterone



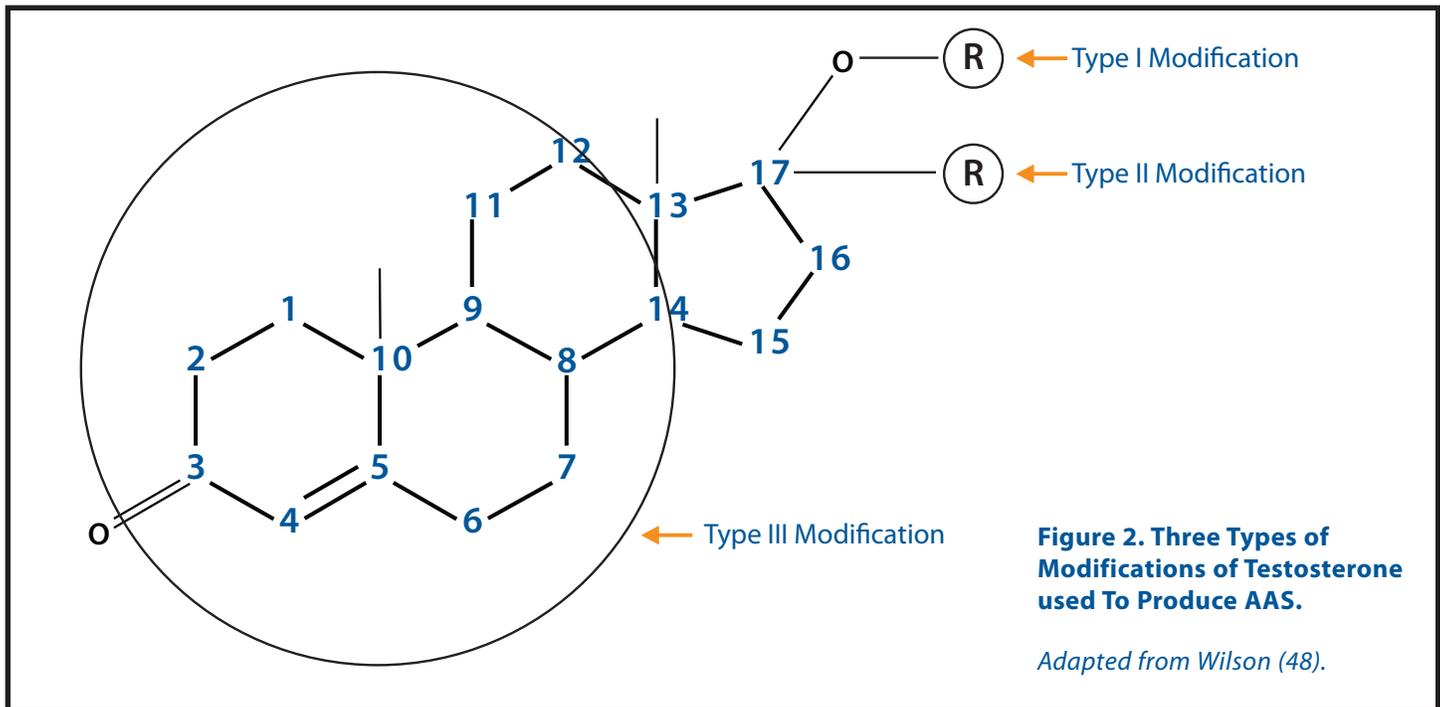


Figure 2. Three Types of Modifications of Testosterone used To Produce AAS.

Adapted from Wilson (48).

Most often AAS contain a combination of a ring modification and either esterification or alkylation modifications (48). The goals of the creation of synthetic compounds that require modifications to the base testosterone molecule are to 1) delay the degradation of the AAS in an attempt to maintain blood levels of the drug for longer periods of time, 2) to magnify the anabolic effects while minimizing the androgenic effects, and 3) supply the drug in mass so as to overpower the catabolic pathway (48). Many AAS drugs have been created, with varying levels of success, in an attempt to meet these goals. However, to date there are no AAS that have been developed that contain a pronounced anabolic potency, while having no androgenic effects (35). It is important to note that with the creation of new AAS, the subsequent modifications result in alterations in the drugs anabolic to androgenic ratio and also modifies the potential side effects that can occur in response to

the drug (43). As new drugs have been developed, different methods of administration have been proposed. Generally, AAS can be administered in several ways: 1) oral consumption, 2) intramuscular injection, or 3) transdermal administration (27). Table 1 presents a summary of the most commonly used AAS and their method of administration.

What are the Physiological Effects of Anabolic-Androgenic Steroids?

The belief that the use of AAS can increase muscle mass and the ability to develop muscular strength is widely held among the sporting community (6, 16). Much of the early research on the effects of AAS was considered to be inconclusive and some organizations suggested that AAS produced no ergogenic benefits (1). Contemporary literature clearly shows that the administration of testosterone to hypogonadal (low testosterone

levels) men (7, 9, 31, 41, 47), HIV patients (38), and suprapharmacological dosages to eugonadal (normal testosterone levels) men (6, 17, 18, 26) can result in increases in fat-free mass, muscular size, and muscular strength.

One of the most noted clinical studies was performed by Dr. Shalender Bhasin and colleagues (6) where supraphysiologic dosages of testosterone enanthate were administered to a cohort of 40 healthy eugonadal men who ranged from 19 to 40 years of age. One of the key aspects to this investigation was that the 40 subjects were randomly divided into four equal groups: 1) steroid and resistance training, 2) steroid and no-exercise, 3) placebo and resistance training, and 4) placebo and no-exercise. Depending on the group assignment, the subjects either received an intramuscular injection of either 600 mg of testosterone enanthate or a placebo weekly for 10 weeks. Results of this study

Table 1. Generic and Trade Names for Common Anabolic Steroids

Generic Name	Trade Names	Means of Administration
Danazol	Danocrine	Oral
Ethylestrenol	Maxibolin	Oral
Fluoxymesterone	Halostestin Ultandren Android-F	Oral Oral Oral
Mesterolone	Proviron Mestranum	Oral Oral
Methandrostenolone	Dianabol	Oral
Methyl Testosterone	Oreton Methyl Android Testered Virolin	Oral Oral Oral Oral
Oxandrolone	Anavar Oxandrin	Oral Oral
Oxymetholone	Anadrol-50	Oral
Stanozolol	Winstrol	Oral
Boldenone Undecylenate	Parenabol Equipoise	Injectable Injectable
Dromostanolone	Drolban	Injectable
Methanolone Enanthate	Primoblan-Depot	Injectable
Nandrolone Decanoate	Anabol Deca Durabolin	Injectable Injectable
Nandrolone Phenpropionate	Durabolin	Injectable
Nandrolone Undecanoate	Dynabolan	Injectable
Testosterone Enanthate	Delatestryl Sustanon	Injectable Injectable
Testosterone Cypionate	Depo-Testosterone	Injectable
Testosterone Propionate	Oreton	Injectable
Testosterone Undecanoate	Andriol Restandol	Injectable Injectable
Trenbolone Acetate	Prabolan	Injectable
Testosterone	Androderm Androgel Testim Testoderm	Transdermally Transdermally Transdermally Transdermally

Note: adapted from Stone and O'Byrant (42), Friedl (20), and Hall & Hall (27).

demonstrated that the men who were given testosterone enanthate and resistance training experienced a significantly greater increase in fat free mass (+6.1 kg), quadriceps area, and triceps area than any of the other groups. This group also experienced the greatest increases in maximal bench press (+22%) and back squat performance (+38%) when compared to the other groups. This data is striking in that the placebo and exercise group only experienced a 21% increase in back squat performance, while the group that received the drug treatment and did no exercise experienced a 19% increase in maximal back squat performance. Interestingly, this study also reported that no side effects occurred in any of the men participating in the investigation. This study gives clear evidence that supraphysiologic dosages of testosterone enanthate stimulate significant increases in fat-free mass, muscle size, and muscular strength, especially when combined with a rigorous resistance training program.

Based upon the available contemporary scientific literature, it appears that the ergogenic effects associated with AAS administration occur in a dosage-dependent fashion, suggesting that higher dosages of testosterone produce greater adaptive responses (8). Additionally, these adaptive responses appear to be magnified when drug administration is coupled with a resistance training program and a proper diet (2, 6).

What Are Designer Steroids?

Designer steroids are compounds which are generally not tested for by WADA, thus, because they are not on the official

testing protocols they are in fact considered undetectable (11, 12). A designer steroid can be classified in one of two ways: 1) a steroid previously identified but never marketed or approved for human use (11) or 2) a new steroid entity that has never been documented in the scientific literature (12). Once a designer steroid is detected new drug testing protocols are developed, placed into drug screening practices, and often retrospective testing on frozen urine samples are undertaken (34). To date, only three designer steroids have been noted in the scientific literature (11, 12, 39).

In 2002, the first so called designer steroid, norbolethone, was isolated in the urine samples of two female athletes by the UCLA Olympic Analytical Laboratory (11). Norbolethone was originally documented some 30 years ago (10, 25). Catlin et al. (11) have hypothesized that norbolethone was never marketed, because of noted toxic effects in animal studies (46) and/or reports of the drug causing menstrual irregularities (24,25). Research conducted on norbolethone in the 60's reports that the drug had an anabolic activity that was 20 times higher than its androgenic activity (10, 11), thus making this drug very attractive to athletes looking to gain a competitive edge. After its discovery, a new drug testing protocol was developed for norbolethone, which was subsequently added to the list of banned substances presented by WADA and is currently tested for during drug screening.

The second and most famous designer steroid is tetrahydrogestrinone, or THG,

as it is more commonly known. THG is the drug that brought national attention to what it often referred to as the Bay Area Laboratory Cooperative (BALCO) Scandal(33, 34). The BALCO scandal and its implication of many professional athletes have brought national attention to the problems associated with sports doping.

THG was discovered in 2003 by the UCLA Olympic Analytical Laboratory after a syringe with an unknown anabolic compound was anonymously sent to the United States Anti-Doping Agency (USADA) (12). Unlike norbolethone, THG is a new chemical entity and would have remained undetectable if the syringe containing it had not been sent to USADA. THG is closely related to gestrinone, a progestin, and to trebolone a veterinary androgen. A small modification of gestrinone resulted in the creation of THG. Since THG is a new steroid entity, there is very little information about the safety and anabolic effects of this drug (3). Death et al. (15) were the first to demonstrate that THG is a potent androgen with progestin like properties. Additionally, Friedel et al. (19) confirm that THG is a potent androgen and also demonstrate that it has a high binding affinity for glucocorticoid receptors, which may suggest that it is also an anticatabolic drug. There are no scientific studies on the side effects of THG, but due to its similarities in structure to gestrinone, side effects of THG might be similar to those noted for gestrinone. In women who have been treated with gestrinone, several androgenic side effects have been reported including increased presence of acne, weight gain, voice change, and hirsutism

(heavy hair growth) (13, 14). In order to screen for THG in athletes, Catlin et al. (12) have developed a reliable testing protocol that has been added to the test battery conducted by WADA.

The third designer steroid is the compound known as madol or desoxymethyltestosterone (DMT) (39). The UCLA Olympic Analytical Laboratory isolated this steroid in 2004 from an oily product allegedly containing an anabolic steroid that was not on any of the WADA testing protocols (39). Later in 2005 a group of scientists from Montreal discovered a designer steroid which they called desoxymethyltestosterone (DMT), however when looking at the chemical structure this drug is in fact madol. As with norbolethone, madol was first reported in the scientific literature in the 1960's and was never marketed or approved for use by humans (32). Presently, there is no known safety or efficacy data for madol, but when looking at early studies in rat models, madol's anabolic activity was reported as being 160% of that reported for testosterone and its androgenic activity was 60% that of testosterone (39). Currently, WADA has added screening procedures for madol to its drug testing protocols.

The entrepreneurial exploits of those who have developed these designer steroids suggests that the manipulation of the steroid skeleton can result in custom designed androgens with the express purpose of yielding the benefits of androgens while allowing the individual to avoid the punitive effects of a failed drug test (28). It is likely that many more drugs are being developed

covertly so that athletes can beat current drug screen practices.

What is on the Horizon?

Recently, researchers have suggested that androgen therapy will soon go through a fundamental change as a new class of molecules has been theorized. This proposed new class of molecules are selective called androgen receptor modulators (SARMs) and are designed to target specific androgen receptors to elicit specific desirable outcomes (36). Gao et al. (22) report that they have developed two SARMs that are capable of fully stimulating androgen receptors in the levator ani muscle while only partially stimulating the prostate. They also report that these compounds exhibit tissue selectivity without suppressing testosterone's effects on muscle. In another study, Gao et al. (23) compared the effects of dihydrotestosterone, an AAS, with that of a SARM labeled S-4 on skeletal muscle, bone mass and muscular strength of orchidectomized (castrated) rats. Results of the study demonstrated that S-4 exhibited strong anabolic effects resulting in increases in muscular strength and mass along with marked increases in bone mass. However, unlike the dihydrotestosterone group, the S-4 treatment resulted in significantly less androgenic activity, particularly in regard to agonist activity at the prostate. Taken collectively, the development of SARM drugs has the potential to deliver anabolic activities to selective tissues and potentially decrease negative key side effects that can be associated with the use of AAS (36).

While the development of SARMs is an exciting proposition for individu-

als with osteoporosis (37, 40), muscle wasting associated with HIV (5), anemia, various classifications of muscular dystrophies (4), and sarcopenia, there is a distinct possibility of eliciting use infiltrating the world of sport. SARMs may be particularly attractive to athletes, as these drugs offer the anabolic effects without the androgenic effects which are commonly associated with traditional AAS use.

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Side Effects of Steroid Use

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The positive effects of anabolic androgenic steroid (AAS) use on muscle strength and size have been well documented in the scientific literature. This article does not seek to discuss the effects of AAS on size and strength of skeletal muscle or the mechanisms of those actions as they are somewhat controversial and discussed elsewhere (3,17). Instead, this article focuses on the reported side effects resulting from AAS use ranging from the highly publicized to obscure, from the relatively harmless to potentially fatal. A short history of AAS is first presented along with common misconceptions, followed by a brief overview of the effects of AAS use on the major systems of the body. For a more detailed explanation of AAS, their mechanisms of action, and their physiological and psychological effects, the reader is directed to the reference section. In particular, a few in-depth and thorough review papers (and Chapter 29 in the text by Brooks et al. 3) have been published and are quite recent (4,6,9,11,13,16,21).

The physiologist Charles E. Brown-Sequard is credited with making the first public claims about the effects of AAS in 1889 (9,10). However, it was not until the 1930's (most sources cite

1935) that the first androgen of androsterone was isolated by Butenandt (9). In the early days, testosterone derivatives were synthesized not for athletic prowess or aesthetic perfection, but for the beneficial effects related to certain disease states like hypogonadism (21). Since then, AAS have been used therapeutically for treating depression, augmenting muscle mass in older men, and attenuating the catabolic effects of diseases/conditions associated with muscle wasting (e.g. HIV infection) (6). With the ushering in of the mid-twentieth century and the beginning of the sports era came a quest to maximize athletic performance through whatever means possible. Aside from traditional training techniques, AAS usage was seen by many as the ticket to being stronger, running faster, and jumping higher. This was first documented among Soviet weightlifting teams in the early 1950's (21). The story is that the weightlifting team physician for the U.S., Dr. John Ziegler, learned from a Soviet physician at the World Weightlifting Championships in Vienna in 1954 that the Soviet lifters were using testosterone to enhance performance (2,11). Over the next few years, Dr. Ziegler worked with Ciba Pharmaceutical Company to release the synthetic testosterone deriva-

tive Dianabol in 1958 (2). The IOC placed AAS on its banned substance list in 1976 (11). The late twentieth century's increased drive for athletic excellence combined with societal pressures to achieve a more aesthetic appearance is a recipe for use, overuse, and abuse of AAS.

A common misconception often arises from the fact that testosterone is a naturally occurring substance in the body. While the average adult male produces 6 – 7mg of testosterone daily (6,20), the error is in thinking that exposing the body to higher than natural/normal levels is okay since it is a compound (or very closely mimics one) that the body is designed to deal with. The notion that testosterone is a naturally occurring substance in the body and therefore introducing supraphysiologic levels far in excess of normal is fine is altogether false and a dangerous premise from which to base one's actions, particularly in light of the fact that the introduced substance is synthetic, not natural.

While some side effects off AAS use are quite visible and apparent, others are more subtle. The vast majority of the effects that AAS have on the cardiovascular system largely go unnoticed except in the most vigilant individuals or until a serious medical complication arises. Hypertrophy or excessive growth of cardiac muscle, specifically the left ventricle (the main pump of the heart) independently predicts cardiovascular mortality across diverse disease states (15). Left ventricular hypertrophy (LVH) is a common finding in heavy resistance trained individuals and any potential long-term health conditions as a result

have yet to be elucidated. However, this hypertrophy seems to be more pronounced in AAS users (1,6,9,11,16,22). It remains to be determined if the AAS exerts a direct effect on LVH, or if the increased volume and/or intensity of training that often accompanies AAS usage is the cause. Diastolic dysfunction has been observed in AAS users (5,6,22) as has increased septal wall thickness (5), LV mass and volume (5), and arrhythmias (6) so the association with AAS and unfavorable cardiac adaptations appears to be more than just coincidence. Myocardial infarction (21), stroke (9,11,16), and sudden cardiac death (11,21) have also been linked to AAS usage. Brooks et al. (3) report that heart damage appears to be the biggest long-term risk of heavy steroid use.

Use of AAS has been shown to have adverse effects on the vasculature as well. Specifically, high blood pressure (6,16), thrombosis (1,6), and endothelial dysfunction (1) have been reported in individuals using AAS. Interestingly, Alaraj et al. (1) report separate case studies in which two young healthy males, who had admittedly been using high dosages of AAS, suffered spontaneous subdural haematomas (bleeding in/on the brain caused by hemorrhage). The authors speculate that AAS use was linked to vascular changes that predisposed these individuals to subdural haematoma (a very rare occurrence in young, healthy individuals), particularly during the intense Valsalva maneuvers which accompany heavy resistance training (1). The consequences of these pathologic changes in the cardiovascular system may be acute in the cases of stroke, sudden cardiac death, and subdural haema-

toma, or they may be more chronic and go unrealized for years until a serious or fatal cardiac event occurs as a result of having a negative cardiovascular profile for many years.

Another “silent” side effect of ASS use that seems to be a bit more definitive in the literature is an unfavorable lipid profile, specifically related to low density lipoprotein (LDL/bad cholesterol) and high density lipoprotein (HDL/good cholesterol). There is a strong association with AAS use and high values of LDL cholesterol (7,8,11,13,16,17,21) in addition to low values of HDL cho-

“...heart damage appears to be the biggest long-term risk of heavy steroid use.”

lesterol (7-9,11,13,14,16,17,21). Low values of HDL (good) cholesterol and high values of LDL (bad) cholesterol are independent risk factors for heart/coronary artery disease, so the long term negative effects of an unfavorable lipid profile can not be dismissed. Interestingly, but perhaps not surprising, is that total cholesterol is reported to be unchanged by AAS use (11). This may be expected if the decrease in HDL is roughly equivalent to the increase in LDL cholesterol. Although total cholesterol is not quite as simple as LDL + HDL, for the scope of this discussion that general relationship will be assumed.

Effects of AAS on triglycerides are not as widely agreed upon as cholesterol and some sources indicate triglycerides are elevated (7) while others report no change (11). Brooks et al. (3) actually states that triglycerides (as well as LDL cholesterol) are lowered in response to AAS use, so additional investigation is warranted as triglycerides are an important marker for cardiovascular disease risk along with cholesterol.

The liver often receives a great deal of attention when discussing potential harmful side effects of AAS use. Liver toxicity is a common finding in AAS users as identified by increased liver enzymes (3,6,21). Extreme cases such as liver failure have been reported (6) as have other severe liver disorders like peliosis hepatic (presence in the liver of blood-filled cavities) (3), hepatocellular carcinoma (malignant liver tumor) (3) and other tumors (16), and cholestasis (a stoppage in the flow of bile due to an obstruction) (3). Jaundice is a side effect commonly associated with AAS (21) and is the result of liver toxicity with very identifiable symptoms including a yellowish coloring or tint to the eyes, skin, and bodily fluids. Renal complications have also been noted with AAS use, including kidney failure and Wilms’ tumor (a cancer of the kidney) which may be linked to the observation that AAS are weak carcinogens that can initiate tumor growth or promote such growth in the presence of other carcinogens (16).

Some of the most concerning (to AAS users) and visible side effects of AAS usage are psychological, reproductive, and dermatologic. Common psychiatric

effects are aggression, irritability, euphoria, grandiose beliefs, hyperactivity, and dangerous/reckless behavior (9,10). Dependence is often developed and those who stop taking AAS frequently experience withdrawal symptoms like depression, fatigue, and cravings for the drugs (3). In men, the reproductive and endocrine effects result in reduced sperm and testosterone production, testicular atrophy (3), impotence, and prostate hypertrophy (6). Women may experience masculinizing effects such as hair growth on the face and body, deepening of the voice, and baldness (3) as well as other effects like clitoral enlargement, menstrual irregularities, and reduced breast size (6). Both genders are at risk for libido changes, subfertility, and decreased luteinizing hormone and follicle-stimulating hormone (6). The dermatologic side effects include acne, oily skin, gynecomastia (in men), and striae (stretch marks) (6). Finally, the use of needles or syringes for injections presents the risk for bruising, infection, fibrosis, and neuro-vascular injury (6).

Deleterious side effects of AAS use on the musculoskeletal system certainly do not receive the same attention as the effects on the cardiovascular, metabolic, endocrine, and reproductive systems. The main negative effect seems to be related to the connective tissue of the musculoskeletal system, specifically tendon. The major function of tendon is the transmission of force from skeletal muscle to bone. It is well documented that AAS increase the size and strength of skeletal muscle. This change is more rapid than would be the case if no AAS were being used. Skeletal muscle is able to adapt in size and strength rather

quickly, but tendons require much longer for adaptation to occur in mechanical properties (elasticity, stiffness, tensile strength, etc.) (12). If the mechanical properties of a tendon have not adapted enough to effectively transmit the increased forces (as a result of AAS) generated by the contracting muscle, a rupture may occur (13,16).

A rupture is simply a case of the weakest link of the chain breaking. Ruptures usually occur in one of two ways: 1) the tendon is torn from its insertion on the bone (tendon-bone) or 2) the tendon is torn out of the myotendinous junction (tendon-muscle). Ruptures in the middle of a muscle belly or in the middle of a tendon do also occur but they are much rarer and often are the result of an external trauma. It has also been demonstrated that AAS may exert a more direct and physiologic effect on tendons. Overall tendon strength has been shown to decrease due to dysplasia (misalignment) of collagen fibrils within the tendon as a result of AAS usage (9,12,17). This decrease in tendon strength would predispose the tendon to rupture, particularly in the context of rapidly growing skeletal muscles.

Aside from tendon, AAS usage also can have permanent effects on bone. The use of AAS at a young age promotes premature closure of epiphyseal growth plates in the long bones of the immature skeleton resulting in the cessation of vertical growth (3,7,16). Interestingly, it has been reported that young female gymnasts have used AAS not for the positive effects on strength and performance, but to artificially stunt their growth in an attempt to have a more advantageous

body stature in terms of biomechanics as they age (3).

One question that remains largely unanswered is the reversibility of the side effects of AAS upon cessation of use or whether or not the amount and duration of usage has anything to do with the degree of reversibility. In a study by Urhausen et al. (23), the authors conclude that “the alterations in cell counts, HDL cholesterol, liver function and most hormones of the pituitary-testicular axis induced by a long-term abuse of AAS were reversible after stopping medication for over one year.” No clear consensus has been reached at the present time related to the use of AAS (duration, dosages, forms etc.) and reversibility, or the potential for reversibility, of deleterious side effects upon cessation of AAS use.

Many of the authors of the referenced works in this article urge caution when interpreting the results of studies on AAS use. The main cautionary note is that controlled and well-designed prospective studies of the effects of supra-physiologic dosages are extremely rare in the literature. Most prospective studies involve the administration of AAS at levels comparable to those used in therapeutic applications for certain diseases and conditions due to ethical and safety considerations. It is highly unlikely that any institutional review board, ethical committee, or research institution will sanction the administration of AAS in excess of what has been deemed effective and relatively safe for therapeutic use. As a result, it is difficult to make any firm conclusions related to the effects of AAS use based on these studies because

it is not uncommon for AAS users to take in excess of 10-100 times the recommended therapeutic dosages (19). Therefore, much of the consensus on the effects of AAS use has been developed based on retrospective studies, anecdotal claims, and case studies. However, quite a bit of valuable information has been gathered from these types of studies, and while some may argue that nothing can be concluded from studies that are not prospective, double-blind, randomized, controlled, etc., it would seem foolish not to respect the current thinking on the topic of AAS use and heed the advice of professionals in the medical and research fields, just based on common sense if nothing else.

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Sports Nutrition and Supplementation Muscle Building Strategies

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The scientific investigation of various sports nutrition and supplement strategies has undergone a tremendous growth in the last decade. Individuals who are serious about maximizing their genetic potential naturally consider nutrition a primary tenant of their program. The purpose of this review is to provide practical, drug-free nutritional and supplement strategies for increasing lean body mass.

Nutrient Timing

When you consume nutrients has a profound effect on the adaptive response to exercise. For instance, one study determined whether consumption of an oral essential amino acid-carbohydrate supplement (EAC) before exercise results in a greater anabolic (muscle building) response than supplementation after resistance exercise. Six healthy human subjects participated in two trials in random order, PRE (EAC consumed immediately before exercise), and POST (EAC consumed immediately after exercise). These investigators discovered that the total net phenylalanine uptake across the leg was greater ($P = 0.0002$) during PRE (209 ± 42 mg) than during POST

(81 ± 19). Phenylalanine disappearance rate, an indicator of muscle protein synthesis from blood amino acids, increased after EAC consumption in both trials. Therefore, net muscle protein synthesis is higher when an EAC solution is consumed immediately before resistance exercise versus after exercise. This may be due to the increase in muscle protein synthesis as a result of increased delivery of amino acids to the leg (9). However, inasmuch as this was an acute study, the important clinical endpoint is whether one can actually accrue more skeletal muscle mass as a result of utilizing a nutrient timing strategy.

Another study compared the effects of 14 weeks of resistance training combined with timed ingestion of isoenergetic (i.e. same total calories or energy) protein versus carbohydrate supplementation on muscle fiber hypertrophy and mechanical muscle performance. Supplementation was administered before and immediately after each training bout. On non-training days, subjects consumed their supplements in the morning. Muscle biopsy specimens were obtained from the vastus lateralis muscle and analyzed for muscle fiber

cross-sectional area. After 14 weeks of resistance training, the protein group showed hypertrophy of type I ($18\% \pm 5\%$; $P < .01$) and type II ($26\% \pm 5\%$; $P < .01$) muscle fibers, whereas no change above baseline occurred in the carbohydrate group. Squat jump height increased only in the protein group, whereas countermovement jump height and peak torque during slow isokinetic muscle contraction increased similarly in both groups. In conclusion, the timed ingestion (pre- and post-exercise) of dietary protein is superior to an isoenergetic amount of carbohydrate.

From the standpoint of gaining skeletal muscle mass, it is evident that consuming carbohydrate is not necessary. However, one could propose that the addition of carbohydrate as well as insulinotropic protein (e.g. peptides, protein hydrolysates) may enhance the anabolic response. A recent investigation examined postprandial (after meal) plasma insulin and glucose responses after co-ingestion of an insulinotropic protein hydrolysate with and without additional free leucine with a single bolus of carbohydrate in male patients with long-standing Type 2 diabetes

(n = 10) and healthy controls (n = 10). The investigators concluded that the co-ingestion of a protein hydrolysate with or without additional free leucine strongly augments the insulin response after ingestion of a single bolus of carbohydrate (6). Further work needs to determine if this can be applied to an athletic population.

Fast and Slow Proteins

Boirie et al.(2) found that a 30 gram feeding of casein protein versus whey protein had different effects on post-prandial protein gain. Both whey and casein are proteins derived from milk. In essence, they showed that whey protein is absorbed very quickly producing peak levels of amino acids at approximately 60-90 minutes after ingestion and then returning to baseline levels at approximately three to four hours post-ingestion. Casein on the other hand produced a much slower and less dramatic rise in amino acid levels peaking at approximately 60-90 minutes but maintaining higher levels of amino acids (versus baseline) over the entire seven hour time frame.

Evidently, the differences in digestion and absorption translate into differences in protein metabolism. Whole body protein breakdown was inhibited 34% by casein ingestion but not by whey. Whey protein ingestion stimulated protein synthesis by 68% while casein stimulated protein synthesis to a lesser extent (+31%). However, when they looked at the 'net leucine balance' over the 7-hour time period after ingestion, casein ingestion resulted in a significantly higher net balance (i.e., post-feeding protein deposition was greater). On the other

hand, a recent investigation showed no differences in the anabolic effects of whey or casein. Healthy volunteers were randomly assigned to one of three groups. Each group consumed one of three drinks: placebo (PL; n = 7), 20 g of casein (CS; n = 7), or whey proteins (WH; n = 9). Volunteers consumed the drink 1 h after the conclusion of a leg extension exercise bout. They discovered that the Ingestion of both CS and WH stimulated a significantly larger net phenylalanine uptake after resistance exercise, compared with the PL (PL -5 +/- 15 mg, CS 84 +/- 10 mg, WH 62 +/- 18 mg). Amino acid uptake relative to amount ingested was similar for both CS and WH (approximately 10-15%). Thus, the acute ingestion of both WH and CS after exercise resulted in similar increases in muscle protein net balance, resulting in net muscle protein synthesis despite different patterns of blood amino acid responses (9).

From the limited data, the authors of the research suggest that casein protein may provide more benefit than whey protein. What this means in a practical sense is that the results are not fully understood. However, one could speculate that if you were to consume a single protein source for gaining muscle mass, casein may be preferable over whey. It should be noted that there is no evidence that consuming a diet high in protein has any adverse renal effects (7,10).

Essential Amino Acids plus Carbohydrate

The ingestion of the essential amino acids (EAA) has been shown to produce a significant anabolic effect. For instance, thirty-two untrained young

men performed 12 weeks of resistance training twice a week, consuming ~675 ml of either, a six percent carbohydrate (CHO) solution, six gram EAA mixture, combined CHO + EAA supplement, or placebo (PLA). Blood samples were obtained pre- and post-exercise (week 0, 4, 8, and 12), for determination of glucose, insulin, and cortisol. 3-Methylhistidine excretion and muscle fiber cross-sectional area (fCSA) were determined pre- and post-training. Post-exercise cortisol increased ($p < 0.05$) during each training phase for PLA. No change was displayed by EAA; CHO and CHO + EAA demonstrated post-exercise decreases. All groups displayed reduced pre-exercise cortisol at week 12 compared to week zero. Post-exercise insulin concentrations showed no change for PLA. Increases were observed for the treatment groups, which remained greater for CHO and CHO + EAA than PLA. EAA and CHO ingestion attenuated 3-methylhistidine excretion 48 hours following the exercise bout. CHO + EAA resulted in a 26% decrease while PLA displayed a 52% increase. But most importantly, what happens to skeletal muscle fiber size?

Muscle fiber cross-sectional area (fCSA) increased across groups for type I, IIa, and IIb fibers, with CHO + EAA displaying the greatest gains in fCSA relative to PLA. These data indicate that CHO + EAA ingestion enhances muscle anabolism, following resistance training to a greater extent than either CHO or EAA consumed independently. Accordingly, the synergistic effect of CHO + EAA ingestion maximizes the anabolic response presumably by attenuating the post-exercise rise in protein degradation (1,13,16).

Creatine

There is robust evidence to show that regular creatine supplementation increases total muscle creatine (TCr) concentration by 20 – 40%, improves skeletal muscle mass, and enhances exercise performance (8,12,14,15). The increase in stored phosphagens allows for an enhanced ability to resynthesize phosphocreatine (PCr) thus promoting an ergogenic benefit for short-duration, high-intensity activities (e.g., weight lifting, sprinting, etc). Interestingly, creatine directly influences cellular physiology by increasing the expression of Type I, IIa, and IIx myosin heavy chain (MHC) as well as myogenin and MRF-4 mRNA, protein (10,11) and stimulating satellite cell proliferation (26, 27). On the practical side, it is not clear if there is an optimal method of enhancing intramuscular creatine uptake. For instance, it is known that the consumption of carbohydrates with creatine may facilitate creatine uptake into skeletal muscles. However, the enormous carbohydrate load used in previously published creatine loading studies may be an impractical method of improving intramuscular creatine concentrations (12).

“...creatine is clearly the single most effective dietary supplement for enhancing gains in anaerobic performance...”

In an intriguing investigation from the University of Western Australia, scientists evaluated the efficacy of three different creatine (Cr) loading procedures and 2 different maintenance regimes on intramuscular Cr concentrations (11).

The three loading phases were as follows:

1. Cr (4 x 5 grams per day, for five days)
2. Cr + glucose solution (same Cr dosage; subjects consumed creatine followed by one gram glucose/kg body weight, dissolved in 500 ml water 30 minutes after the second and fourth daily doses).
3. Cr + exercise (cycling exercise performed one hour after ingesting the second Cr dose).

The two maintenance doses studied were as follows (with a control as well):

1. Two grams Cr daily for six weeks
2. Five grams Cr daily for six weeks
3. No creatine for six weeks

What did they find? TCr concentrations increased significantly more in the Cr + glucose group (+25%) compared to the Cr only (+16%) and the Cr + exercise (18%) groups. There were no significant differences between the Cr only and Cr + exercise groups. Also, PCr stores were significantly elevated in the Cr + glucose (+8%), the Cr + exercise (+9%), but not the Cr only group (+5%).

After the six week maintenance phase, the two grams per day and five grams per day Cr dosages produced similar intramuscular TCr concentrations; however, the no creatine resulted in a

significant decrement in creatine stores. Interestingly, muscle TCr stores had not returned to baseline after six weeks of no creatine.

There are several interesting points about this study. First, it was surprising that exercise plus Cr did not improve intramuscular TCr over Cr alone. One could speculate that repeated sprint exercise (as used in this investigation) may have restricted gastrointestinal absorption and that perhaps exercise of a milder nature may have been more effective. Also, the improvement in TCr subsequent to carbohydrate plus creatine ingestion verifies this loading methodology. However, the dose used in this investigation is still rather high (~773 grams of sugar total over the five day period; that is over 3,000 extra calories). If maintenance of a low fat mass is critical, then the consumption of such high levels of high-glycemic sugars is not recommended. Another interesting observation is that a low daily dose of two grams of Cr is sufficient to maintain high intramuscular TCr stores. To date, creatine is clearly the single most effective dietary supplement for enhancing gains in anaerobic performance as well as increasing lean body mass and muscle fiber size.

In summary, one can reasonably conclude that if you are seeking a fairly rapid improvement in anaerobic performance and lean body mass, it would be sensible to do a loading phase with creatine. However, if time is not an issue, a dose of two to four grams daily should be sufficient to fully saturate skeletal muscle within a month. Furthermore,

the use of high-glycemic sugars to potentiate the uptake of creatine has good support in the scientific literature; however, if the maintenance of low body fat levels is a paramount concern (example: bodybuilders, strength-power athletes in the lower weight classes), then one can still supplement with creatine (minus the sugar) and get significant elevations in total intramuscular creatine concentrations. Moreover, it should be noted that there is no evidence that regular creatine supplementation has any adverse effects (4,5)

Practical Applications

In essence, once you get through the 'clutter' of data, there are several practical strategies you can utilize to promote gains in lean body mass through nutrition.

1. Consume approximately a teaspoon of creatine daily.
2. Consume a combination of protein and carbohydrates (roughly 25 grams of protein with an equal amount of carbohydrates [less carbohydrates if you are a physique athlete]) 15 – 30 minutes pre-workout and immediately post-workout.
3. Consume a sports drink spiked with protein during a workout.
4. Consume essential amino acids as a stand alone supplement pre and post-workout (it can also be added to a protein shake).
5. Never decrease protein intake.
6. Drink plenty of water.
7. For your meals, consume primarily unprocessed carbohydrates, lean proteins, and health fats (e.g. fish fat, nuts, etc).

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