

# Anabolic steroids – a problem in popular sports

---

Ulrich Hoffmann

---

*Institute of Pharmacology, Ernst-Moritz-Arndt University, D-17487 Greifswald, F.-Loeffler Str. 23 d  
e-mail : jaki@uni-greifswald.de*

## Abstract

The sportsmen self-administering androgenic-anabolic agents to improve their performance and their body shape continue to be a problem. After the opening of the East European borders a large number of compounds are offered on the black market and in fitness centres. As a consequence students and children practicing no sport use these agents. Most athletes have only a crude pharmacological knowledge regarding these drugs. Their information are derived from their own experience or experiences of other sportsmen. Therefore warnings concerning the efficacy and potential dangers of steroid misuse are neglected. Studies suggest that anabolic steroids are now the third most commonly offered drugs behind cannabis and amphetamines. The anabolic black market is a lucrative commercial business and its volume amounts to 70 Mill. €/year approximately.

This paper will focus the attention on the common anabolic steroid misconceptions and review the adverse effects and the problems connected with the use of the illicit drugs.

## 1. Introduction

The use of performance enhancing drugs is not limited to elite athletes. Sociocultural standards of beauty for males emphasize strength and muscularity. The broad-shouldered, narrow-hipped male body is idealized in Western media. Weight machines and performance enhancing supplements are widely advertised in health and fitness centers [1].

The number of sportsmen in semi-professional as well as in popular sports self-administering ergogenic pharmacological agents continues to be a problem. Most athletes use anabolic-androgenic steroids (AAS) to obtain a well-trained, athletic, and healthy looking body [2]. Frequently the AAS using athletes of today have a sophisticated knowledge of steroid pharmacology based on their own experiences or anecdotal information. Therefore warnings from healthcare providers informing about potential dangers of steroid misuse are largely disregarded [3,4].

The illicit drugs come from Eastern Europe or South East Asia at the European market. The prevalence of AAS use has been reported in several populations but exact data are limited because students and athletes do not admit the usage of these controlled substances. A recent survey of the Blue Cross and Blue Shield Association [5] reported that steroids were the second most common substances used for athletic performance among 12- to 17-year old people, second to creatine (31 vs 57 %). It is estimated that between 3-12% of male high school seniors have used anabolic steroids [6]. Far more troublesome is an interview of 1000 schoolchildren in England 1998 showing that anabolic steroids had been the third most commonly used drug behind cannabis and amphetamines, revealing that 6.4 % of boys and 1.3 % of girls had been offered steroids [7].

There are different groups that use performance enhancing drugs [8]. Besides the elite athletes who have a definite plan to achieve their goal, also young people who are involved in sport or started attending the gymnastics use these compounds. They see the anabolics as part of the culture and a short cut to their goal. The „recreational users“ take the performance drugs in an effort to enhance sex drive, aggression, stamina and a sense of well being. Often they have only a crude knowledge about the pharmacological databases and adverse effects regarding these drugs. We observe in our region an increasing number of misuses of AAS in young athletes.

The goal of this article is to provide an unbiased overview of the use of the anabolic drugs and will include chemistry, pharmacology, efficacy, adverse effects, and misconceptions among bodybuilders related to anabolic steroid use.

## 2. Chemistry

All androgens possess the cyclopentanophenanthrene nucleus, typical of steroid hormones (Fig. 1).

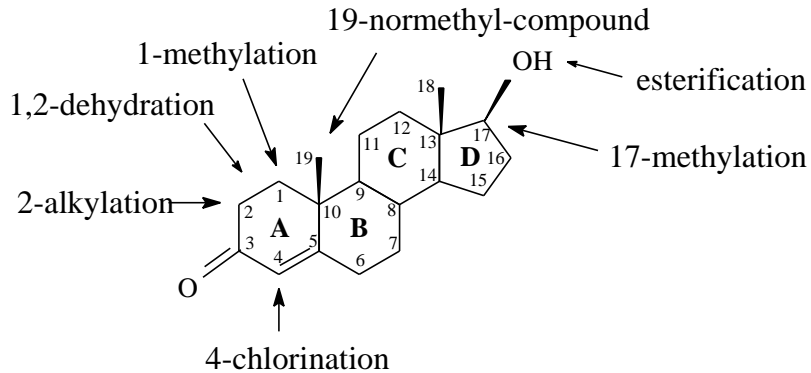


Fig. 1. Basic structure of steroid hormones and the possibilities of chemical derivatization

Testosterone is the major naturally occurring androgen in humans. The structures of testosterone and some selected derivatives used as anabolics are shown in Figure 2. These compounds have been synthesized to maximize the bioavailability, and to prolong the androgenic effects.

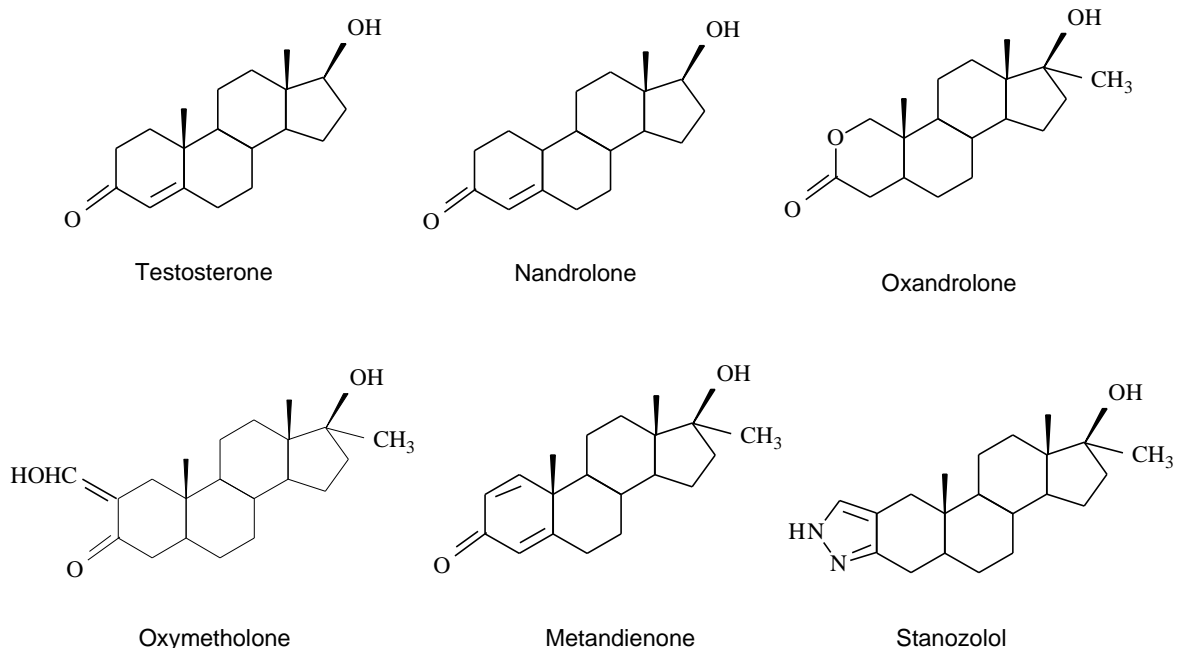


Fig. 2. Structures of testosterone and some of the most common synthetic derivatives used as anabolics

The natural androgen testosterone undergoes a series of biotransformations when taken orally. Injected testosterone also passes rapidly into the blood and to the liver where it is inactivated. The testosterone molecule and some of its synthetic derivatives with unsaturated C-4,5 bond is converted to estradiol by the aromatase thus causing estrogenic effects. A search for more active compounds has yielded derivatives of testosterone [9].

An addition of an alkyl group at position 17a renders the structure orally active. Commonly a methyl group is introduced in this position (Fig 2). In other C-17a-alkylated androgens (norethandrolone, ethylestrenol, norbolethone), an ethyl group is present. The C-17a alkylation markedly retards the hepatic metabolism and thus allows the use of orally effective compounds. All oral androgens are 17a-alkylated with exception of methenolone.

Esterification of the 17-hydroxy group delays the biodegradation. Short-chain esters (C<sub>2</sub>- C<sub>4</sub>) give raise to short-acting steroids, whereas long-chain esters (C<sub>7</sub>- C<sub>10</sub>) are longer acting agents. These derivatives are highly androgenic and because of the their unsaturated C-4,5 double bond they can be aromatized.

Substitution of hydrogen for the methyl group in position C-19 results in 19-nortestosterone (nandrolone). Esterification of nandrolone yields products with more stabil and anabolic properties. The compounds are applied by i.m. injection and have a long bioavailability. Oxandrolone has an oxygen molecule at the C-2 position resulting in a lactone ring, whereas oxymetholone contains a hydroxymethylgroup at this position. At present metandienone (Dianabol<sup>®</sup>) is presumably the most frequent used anabolic among bodybuilders. The substance has been banned since 1987 in the United States and Western Europe. Metandienone or metandrostenolone has an additionally double bond at C-1,2 position in comparison to testosterone. Stanolozol was the first anabolic active steroid with a heterocyclic pyrazole ring. It is banned in Germany but approved for oral application in the USA.

Despite numerous trials synthesizing a pure anabolic steroid has failed. The partial dissociation of the anabolic and androgenic effects in the synthetic steroids is different from one substance to another and is not a result of receptor binding [10]. All anabolic steroids possess at least some androgenic activity.

### 3. Pharmacological effects

The anabolic steroids are synthetic derivatives of testosterone modified to enhance the anabolic rather than the androgenic effects. They have a number of actions and can be differentiated in :

#### *Androgenic effects :*

- development of primary sexual characteristics in males
- secondary sexual characteristics during puberty (genital size, prostata growth, induction of sperm production, hair distribution, deep voice)
- muscular-skeletal configuration
- psychic changes

and

#### *Anabolic effects :*

- promoting protein synthesis, positive nitrogen balance, muscle growth
- increasing calcium-uptake and stimulation of skeletal growth
- erythropoiesis
- percentual decrease of body fat, V-shaped muscle man
- reuptake of electrolytes

The known medical indications for taking AAS are hypogonadism, catabolic disorders as muscle wasting, growth retardation, tissue healing, cachexia, and osteoporosis, aplastic anaemia, virile climacteric period, and mama carcinoma. The influence of AAS on the performance enhancement, mainly the increase in muscle mass and strength, is controversially discussed in the literature. Especially in combination with weight training and an adequate protein rich nutrition AAS show beneficial effects but randomised controlled trails do not exist.

The athletes use the drugs in cycles of gradually increasing doses and increasing numbers of agents combined together (Table 1).

Table 1: Commonly used anabolic steroids in popular sports

Oral drugs	Injectable drugs
Ethylestrenol, Fluvoxymesterone	Testosterone salts : cypionate, decano-ate, propionate, phenpropionate
Methyltestosterone, Danazol, Furazabol	Nadrolone salts : decanoate, phenpropionate
Oxymetholone, Oxandrolone	Boldenone undecylenate, Clostebol caproate, - propionate
Metandienone, Stanozolol	Methenolone enanthate, Trenbolone acetate, Oxabolone cipionate

These cycles have a duration between 6-12 weeks with a rest period between the uptake and frequently involve a combination of oral agents and long-acting injectable agents. This process is called stacking [11]. In the rule 2-3 cycles per year are required. The doses vary between therapeutic levels and 50 to 100 times over dosing. In pyramiding, doses of the steroid are gradually increased, then decreased over the period of the cycle. The misuse amounts vary between 10 to 1000 mg per day dependent on the type of sport. As a rule higher dosages of AAS do not lead to the increase of muscle mass and strength gain but more adverse effects have been observed. Because of the increasing concentration of metabolites also more interaction are registered, too [12]. Especially the incidence of cardiovascular diseases are increased at higher dosages. Likewise the kinetic interactions between different anabolics have a large risk potential.

### *Adverse effects*

The major side effects of anabolic steroids are hepatotoxicity, cardiovascular changes, reproductive and endocrine disturbances, dermatological, and psychiatric effects [13] (Table 2). Especially C-17a alkylated AAS as Dianabol<sup>®</sup> have a larger rate of incidence for neoplastic lesions [14].

### *Hepatic effects*

The orally active anabolic steroids, particularly 17a methyl derivatives are strongly associated with jaundice, hepatic carcinoma and peliosis hepatis. Elevations in aspartate, and alanine transaminase, lactate dehydrogenase, and alkaline phosphatase have been reported in bodybuilders [15]. Among benign lesions, diffuse hyperplasia and focal nodular hyperplasia have been reported. Non-alkylated intramuscular agents are much less likely to produce liver damages [16].

### *Kidney*

Possible renal side effects of AAS are discussed controversially. Elevated serum urea, serum uric acid, and hyperphosphataemia could be induced by anabolics [17]. Nephrosclerosis with obstructive glomerulosclerosis and tubulo-interstitial damage was observed in a bodybuilder using clenbuterol and testosterone [18].

Table 2 : Common adverse effects of anabolic steroids

Organ	Effects
liver	elevated enzymes (CK, LDH, ALT, AST, GGT) <sup>?</sup> cholestasis, peliosis hepatis liver cell carcinoma, hepatic neoplasms
heart circulation system	cardiomyopathy, haematokrit ↑ HDL ↓, LDL ↑, triglycerides ↓
endocrine system	LH ↓, FSH ↓, TSH ↓
effects in males	spermatogenesis ↓, prostata hypertrophy, - carcinoma , size of testes ↓, feminisation
effects in females	virilization, voice deepening, menstrual irregularities, clitoral hypertrophy, breast mass ↓,
skelet, muscle	premature closure of epiphysis (children), rhabdomyolysis ?
skin	alopecia, acne, hirsutism, oily hair and skin
psychiatric effects	depression, aggression ?, libido ↑, antisocial behavior

CK: creatin kinase, LDH: lactate dehydrogenase, ALT: alanine aminotransferase, AST: aspartate aminotransferase, GGT: gamma-glutamyltransferase, HDL: high density lipoprotein, LDL: low density lipoprotein, LH: luteinising hormone, FSH: follicle-stimulating hormone, TSH: thyroid stimulating hormone.

### *Cardiovascular system*

Use of AAS lead to detrimental changes in lipid profiles with increased low density and decreased high density lipoproteins [19]. Triglyceride levels are decreased by the exogenous administration. An increase in LDL levels might contribute to arteriosclerosis if these drugs are administered over a longer period [20]. Thus AAS have the potential to thrombus formation, coronary artery vasospasm, and enhanced coagulation enzyme activity. The development of myocardial ischaemia and cardiomyopathy is reported in young, formerly healthy patients [21]. These effects are serious and will persist after cessation of AAS.

### *Endocrine and reproductive effects*

Anabolic steroid administration produces a dose-dependent depression of luteinising hormone (LH), and follicle stimulating hormone (FSH). Because both LH and FSH are required for spermatogenesis these changes lead to decline in sperm density, sperm count, and motility. Infertility is a common effect of steroid use when high doses were taken chronically. A reduction in testicular volume can be observed and there is a risk of prostatic carcinoma [22]. AAS can also led to feminisation in males through conversion of testosterone to estrogens by aromatisation.

In women the agents can induce hirsutism, acne, deepening of voice, clitoral hypertrophy, decreased breast mass and menstruation, and male pattern baldness [23].

### *Muscular-skeletal effects*

If applied in children androgens induce a premature closure of the epiphysis resulting in a growth retardation. There are reports of tendon damage, mostly in powerlifters, although

ligamentous ruptures may be due to the excessive loads. The arrangement and contractility of myofibrills and collagen fibers may be altered leading to deterioration in plasticity [24]. Rhabdomyolysis, or acute skeletal muscle destruction may occur after intake of anabolic androgenic steroids in combination with weight-training programmes [25].

#### *Behavioural effects*

The effects of AAS on this field is discussed controversially. A study with testosterone in normal persons demonstrated no adverse long term changes in behaviour [26]. However, some reports have documented an aggressive behaviour in response to provocation. Various psychotic symptoms and manic episodes may also be associated with steroids [27,28].

#### **4. Conclusion**

The most consumption of androgens is by recreational bodybuilders who take them for cosmetic purposes. Performance-enhancing drugs are a part of the culture and it is no wonder that some teenager are taking these substances without going in for sports. Sociocultural standards of beauty for males emphasises strength and muscularity. Indeed, for the majority, these improvements that could be achieved through the use of steroids or other agents can equally be achieved through dietary and training advice. Considering the biological effects and potential adverse effects administration of androgenic anabolic steroids should be avoided. Many of the detrimental effects on health seem to be reversible. However, the action on the cardiovascular system, the liver toxicity and psychiatric effects cause the most severe long time consequences of anabolic steroid use.

The pharmacological knowledge about these substances is based most frequently on both subjective experiences and anecdotal informations. For this reason, warnings regarding the lack of efficacy and potential dangers of steroid misuse are disregarded.

By the shifting of the misuse from elite sport to the popular sport this problem has reached a wider basis and can hardly be controlled. Additionally, the presence of banned substances on the black market substantially increase the risk of their misuse.

On the basis of recent studies and the literature published until today young adults should be early advised about the health risks of anabolic steroids.

#### **References**

- [1] Labre MP, Adolescent boys and the muscular male body ideal. *J.Adol.Health* 30: 233-242 (2002)
- [2] Ayotte C, Lévesque JF, Cléroux M, Lajeunesse A, Goudreault D, Fakirian A. Sport Nutritional Supplements: Quality and Doping Controls. *Can.J.Appl.Physiol.* Suppl 26: S 120-129 (2001)
- [3] Kutscher EC, Lund BC, Perry PJ. Anabolic steroids: A review for the clinician. *Sports Med.* **32**: 285-296 (2002)
- [4] Dawson RT. Drugs in sport. The role of the physician. *J.Endocrinol.* 170: 55-61 (2001)
- [5] Blue Cross and Blue Shield Association. Health Competition Foundation national survey on performance enhancing drugs in sports. Blue Cross and Blue Shield Association [online]. From URL : <http://www.bcbs.com>, Jan 2001
- [6] Yesalis CE, Bahrke MS, Kopstein AN, Kennedy NJ. Incidence of anabolic steroid use. A discussion of methodological issues.  
In : Yesalis CE (ed). *Anabolic Steroids in Sport and Exercise*, 2<sup>nd</sup> Edition. Champaign. 2000, IL: *Human Kinetics Publishers*, pp 73-115
- [7] Clarke J. Anabolic steroids – a growing problem. *Network Northwest. Liverpool. Healthwise Liverpool*, Edition No. 10
- [8] Silver MD. Use of ergogenic aids by athletes. *J.Am.Acad.Orthop.Surg.* 9: 61-70 (2001)
- [9] Shahidi NT. A review of the chemistry, biological action, and clinical application of anabolic-androgenic steroids. *Cli.Ther.* 23: 1355-1390 (2001)

- [10] Saartok T, Dahlberg E., Gustafson JA. Relative binding affinity of anabolic steroids : Comparison of the binding to the androgen receptors in skeletal muscle and prostate as well as to sex hormone-binding globulin. *Endocrinology* 114: 2100-2106 (1984)
- [11] Mottram DR, George AJ. Anabolic steroids. *Baillière´s Clin. Endocrinol. Metabol.* 14: 55-69 (2000)
- [12] Ritsch M, Mußhoff F. Risks of anabolic drug abuse. A scientific approach to the „black market“. *Sportverl.Sportschad.* 14: 1-11 (2000)
- [13] Parssinen M, Seppala T. Steroid use and long-term health risks in former athletes. *Sports Med.* 32: 83-94 (2002)
- [14] Hickson RC, Ball KL, Faludo MT. Adverse effects of anabolic steroids. *Med.Toxicol.Adverse Drug Exp.* 4: 254-271 (1989)
- [15] Pertusi R, Dickerman RD, McConathy WJ. Evaluation of aminotranferase elevations in a bodybuilder using anabolic steroids : hepatitis or rhabdomyolysis ? *JAOA* 101: 391-394 (2001)
- [16] Ishak KG, Zimmerman HJ. Hepatotoxic effects of the anabolic/androgenic steroids. *Semin.Liver Dis.* 7: 230-236 (1987)
- [17] Strauss RH, Wright JE, Finnerman GA. Side effects of anabolic steroids in weight-trained men. *Phys.Sportsmed.* 11: 87-96 (1983)
- [18] Hartung R, Gerth J, Fünfstück R, Gröne HJ, Stein G. End-stage renal disease in a body-builder: a multifactorial process or simply doping? *Nephrol. Dial.Transplant.* 16: 163-165 (2001)
- [19] Sader MA, Griffiths KA, McCredie RJ, Handelsman DJ, Celermajer DS . Androgenic anabolic steroids and arterial structure and function in male bodybuilders. *J.Am.Coll.Cardiol.* 37: 224-230 (2001)
- [20] Sullivan ML, Martinez CM, Gennis P, Gallagher EJ. The cardiac toxicity of anabolic steroids. *Prog. Cardiovasc. Disc.* 41: 1-15 (1998)
- [21] Vogt AM, Geyer H, Jahn L, Schänzer W, Kübler W. Cardiomyopathy associated with the uncontrolled self-medication of anabolic steroids. *Z. Kardiol.* 91: 357-362 (2002)
- [22] Roberts JT, Essenhigh DM. Adenocarcinoma of prostate in 40-year old bodybuilder. *Lancet* 2: 742 (1986)
- [23] Bahrke MS, Yesalis CE, Kopstein AN, Stepkens JA. Risk factors associated with anabolic-androgenic steroid use among adolescents. *Sports Med.* 29: 397-405 (2000)
- [24] Laseler JT, Russell JA. Anabolic steroid-induced tendon pathology: A review of the literature. *Sci. Sports Executive* 23: 1-3 (1991)
- [25] Braseth NR, Allison Jr. EJ, Gough JE. Exertional rhabdomyolysis in a body builder abusing anabolic androgenic steroids. *Eur.J.Emer.Med.* 8: 155-157 (2001)
- [26] Yates WR, Perry PJ, MacIndoe J, Holman T, Ellingrod V. Psychosexual effects of three doses of testosterone cycling in normal men. *Biol.Psych.* 45: 254-260 (1999)
- [27] Choi PYL, Pope HG. Violence toward women and illicit androgenic anabolic steroid use. *Ann.Clin.Psych.* 6: 22-25 (1994)
- [28] Uzych L. Anabolic-androgenic steroids and psychiatric-related effects: A review. *Can.J.Psych.* 37: 23-28 (1992)