Anabolic- Androgenic Steroids and Athletic Performance Enhancement: A Critical Review.

Mr. Yashdeepsingh Thakur
Mr. Vishal Lahane

[1] *Assistant professor Pharmacology Department, P.R Pote Patil College of Pharmacy, Amravati.*
[2] *Assistant professor, Pharmacology Department, P.R Pote Patil College of Pharmacy, Amravati.*

ABSTRACT

Anabolic-androgenic steroids (AAS), synthetic derivatives of testosterone, are widely recognized for their ability to enhance muscle growth and athletic performance, particularly in strength-oriented sports. These compounds promote physiological effects such as increased protein synthesis, appetite stimulation, bone remodelling, and red blood cell production, ultimately contributing to improved muscle mass and strength. Despite these benefits, AAS use is linked to substantial health risks, including liver dysfunction, cardiovascular complications, acne, gynecomastia, and testicular atrophy in men, while women may experience virilization effects such as voice deepening, excessive body hair growth, and menstrual irregularities.

The ethical and legal challenges surrounding AAS usage are significant, as most sports organizations classify their use as unethical and impose strict penalties, including suspensions and bans, on athletes who test positive. This review critically examines the dual nature of AAS—its potential for enhancing performance versus its health and ethical implications. By balancing these aspects, this paper emphasizes the importance of safeguarding athlete well-being and maintaining the integrity of sports.

Keyword :- *Anabolic-androgenic steroids, AAS, Muscle Hypertrophy, Anabolic Cycle, Muscle mass, Strength etc.*

1. Introduction

Anabolic-androgenic steroids (AAS) are synthetic derivatives of testosterone that have been extensively studied for their ability to enhance athletic performance and promote muscle growth. These compounds mimic the natural androgenic effects of testosterone, facilitating the development of lean muscle mass, increased strength, and improved recovery time, making them particularly appealing to athletes in strength-dependent sports. The global prevalence of AAS use among athletes has raised concerns regarding their health, ethical, and legal implications. Despite their performance-enhancing benefits, AAS use is accompanied by significant risks, ranging from physical health issues to psychological dependence, making it a controversial topic in sports medicine and public health (1, 2).

The anabolic effects of AAS are largely attributed to their interaction with androgen receptors in muscle tissues, where they enhance protein synthesis and nitrogen retention. This leads to increased muscle fiber size, improved endurance, and faster recovery from strenuous activity. Additionally, AAS influence other physiological processes, such as appetite stimulation, bone density enhancement, and red blood cell production, all of which contribute to better athletic performance (3, 4). However, these benefits come at a cost, as the prolonged use of AAS has been linked to severe adverse effects, including cardiovascular diseases, liver toxicity, hormonal imbalances, and reproductive issues (5, 6).

Psychological effects, such as aggression, mood swings, and dependence, are also prevalent among users, further complicating their impact. For female athletes, the use of AAS is particularly concerning, as it can lead to virilization effects, such as a deepened voice, excessive hair growth, and menstrual disturbances. Moreover, the psychological pressures faced by athletes to meet performance expectations often exacerbate the misuse of AAS, highlighting the need for preventive measures and education in this area (7, 8).

Ethical and legal considerations are equally significant in the discourse surrounding AAS use. Most international sports organizations, including the International Olympic Committee (IOC) and the World Anti-Doping Agency (WADA), strictly prohibit the use of AAS, considering it a violation of fair play. Athletes found using AAS face

severe penalties, including disqualification and reputational damage. The illegal procurement and distribution of these substances further complicate their regulation and enforcement (9, 10).

2. Most Commonly Used Anabolic-Androgenic Steroids (AAS)

Anabolic-androgenic steroids (AAS) have become widely recognized as performance-enhancing drugs among athletes, bodybuilders, and recreational users. The following section discusses the most commonly used AAS, highlighting their benefits, usage patterns, and potential risks, based on recent research articles.

1. Testosterone and Its Derivatives
Testosterone, the primary male androgen, remains one of the most commonly used AAS due to its effectiveness in promoting muscle hypertrophy and strength. Testosterone esters, such as testosterone enanthate and cypionate, are frequently administered intramuscularly for sustained anabolic effects. These compounds improve protein synthesis, nitrogen retention, and erythropoiesis, leading to enhanced muscle mass and physical performance. However, their use is associated with cardiovascular risks, gynecomastia, and suppression of endogenous testosterone production (11, 12).

2. Nandrolone Decanoate
Nandrolone decanoate, often marketed as Deca-Durabolin, is widely used for its anabolic effects and relatively mild androgenic activity. It promotes lean muscle gain and bone density while minimizing androgenic side effects. Commonly used by athletes and bodybuilders, this injectable steroid can also alleviate joint pain. However, it is associated with adverse effects like liver toxicity and potential suppression of the hypothalamic-pituitary-gonadal axis (13, 14).

3. Trenbolone
Trenbolone is a highly potent AAS commonly used by bodybuilders for its significant anabolic effects, including increased muscle growth and fat loss. Known for its high binding affinity to androgen receptors, trenbolone enhances protein synthesis and nitrogen retention. Nevertheless, its use is linked to severe side effects such as aggression, insomnia, cardiovascular complications, and potential neurotoxicity (15, 16).

4. Stanozolol (Winstrol)
Stanozolol, an oral or injectable AAS, is a derivative of dihydrotestosterone (DHT). It is popular for its ability to enhance muscle definition and strength without significant water retention. Athletes often use stanozolol to improve physical aesthetics during cutting phases. However, its use can lead to hepatotoxicity, tendon fragility, and alterations in cholesterol levels (17, 18).

5. Oxandrolone (Anavar)
Oxandrolone, commonly known as Anavar, is an oral AAS often chosen for its mild androgenic properties and effectiveness in promoting strength and muscle mass without excessive weight gain. It is particularly popular among female athletes due to its lower risk of virilization. Despite its mild profile, oxandrolone can cause hepatotoxicity and dyslipidemia with prolonged use (19, 20).

6. Methandrostenolone (Dianabol)
Methandrostenolone, also known as Dianabol, is one of the most popular oral AAS for increasing muscle mass and strength rapidly. It enhances protein synthesis and glycogen storage, leading to significant performance improvements. However, its use is often associated with liver toxicity, hypertension, and water retention (21, 22).

7. Boldenone Undecylenate (Equipoise)
Boldenone undecylenate is an injectable AAS initially developed for veterinary purposes but is now commonly used by athletes. It promotes steady muscle growth and enhances red blood cell production. Although its side effects are considered mild compared to other AAS, it can cause androgenic effects, cardiovascular strain, and changes in lipid profiles (23, 24).

8. Drostanolone Propionate (Masteron)
Drostanolone propionate is an injectable AAS derived from DHT. It is valued for its ability to enhance muscle hardness and definition, making it a popular choice among athletes during contest preparation. Despite its benefits, it may cause androgenic side effects and alterations in cholesterol levels (25, 26).

9. Oxymetholone (Anadrol)
Oxymetholone, marketed as Anadrol, is a potent oral AAS known for its rapid and significant effects on muscle mass and strength. It is commonly used during bulking cycles but carries risks such as severe hepatotoxicity, hypertension, and gynecomastia (27, 28).

10. Methenolone Enanthate (Primobolan)
Methenolone enanthate is an injectable AAS with a favorable safety profile, making it a popular choice for cutting cycles. It helps preserve lean muscle mass while promoting fat loss. However, its anabolic effects are relatively mild, and misuse can lead to cardiovascular strain and hormonal imbalances (29, 30).

3.Anabolic Cycles and Usage Patterns:-

Anabolic cycles refer to the planned administration of anabolic-androgenic steroids (AAS) over a specific period to maximize their anabolic benefits while attempting to minimize adverse effects. Users typically cycle AAS in phases, including the "on-cycle" (active usage) and the "off-cycle" (recovery period). While some individuals use a single compound ("monocycle"), most adopt stacking regimens, combining multiple AAS to amplify anabolic effects and achieve specific goals such as muscle mass gain, fat loss, or performance enhancement.

1. Bulking Cycles

Bulking cycles are designed to maximize muscle mass and strength. Testosterone esters such as testosterone enanthate and testosterone cypionate are foundational compounds in these cycles due to their robust anabolic properties and relatively longer half-life. These are frequently stacked with methandrostenolone (Dianabol) or nandrolone decanoate (Deca-Durabolin). Methandrostenolone is favored for its rapid effects on strength and size, while nandrolone contributes to steady muscle gains and joint support. However, bulking cycles often result in water retention, increased blood pressure, and hepatotoxicity when oral steroids like Dianabol are included (31, 32).

2. Cutting Cycles

Cutting cycles aim to preserve lean muscle mass while reducing body fat, primarily used during pre-competition preparation. Compounds like stanozolol (Winstrol), oxandrolone (Anavar), and drostanolone propionate (Masteron) are common in cutting cycles due to their low androgenic activity and their ability to enhance muscle definition without causing significant water retention. Stanozolol, when combined with trenbolone, can significantly increase muscle hardness, but it carries risks of hepatotoxicity and lipid imbalance. Oxandrolone is often included for its mild profile, making it a preferred choice among women and individuals sensitive to androgenic effects (33, 34).

3. Recomposition Cycles

Recomposition cycles focus on building lean muscle while simultaneously reducing fat. Boldenone undecylenate (Equipoise) is a commonly used compound in these cycles due to its steady anabolic effects and minimal aromatization. It is often stacked with testosterone esters and methenolone enanthate (Primobolan) for individuals seeking gradual, sustainable improvements in body composition. Trenbolone is also included in recomposition stacks for advanced users, given its potent anabolic activity and fat-burning properties. However, trenbolone's use is associated with severe side effects such as night sweats, insomnia, and aggression (35, 36).

4. Advanced Stacking Protocols

Advanced users often engage in stacking protocols that combine multiple injectable and oral AAS for synergistic effects. For example, a common advanced stack includes testosterone enanthate as a base, trenbolone acetate for its potent anabolic effects, and oxymetholone (Anadrol) for rapid strength and size gains. While this stack provides remarkable results in terms of muscle hypertrophy, it comes with increased risks of cardiovascular complications, hepatotoxicity, and hormonal imbalances (37, 38).

5. Post-Cycle Therapy (PCT)

PCT is an essential component of any anabolic cycle to restore natural testosterone production and mitigate adverse effects. Compounds like tamoxifen citrate (Nolvadex) or clomiphene citrate (Clomid) are commonly used in PCT to stimulate the hypothalamic-pituitary-gonadal axis. Additionally, human chorionic gonadotropin (hCG) is often incorporated to prevent testicular atrophy and promote endogenous testosterone production. Failure to implement PCT after anabolic cycles can lead to prolonged suppression of testosterone, loss of muscle gains, and psychological effects such as depression (39, 40).

6. Risks of Prolonged Cycles and High Doses Prolonged anabolic cycles or excessive dosages are associated with significant health risks. Cardiovascular issues, including left ventricular hypertrophy, dyslipidemia, and hypertension, are commonly reported among long-term users. Hepatotoxicity is a major concern with oral AAS such as oxymetholone and stanozolol. Furthermore, endocrine disruptions, such as gynecomastia and testicular atrophy, are prevalent in individuals who fail to manage estrogen levels effectively during cycles (41, 42).

7. Trends in Microdosing Recent trends in microdosing AAS have emerged as a strategy to reduce side effects while maintaining performance-enhancing benefits. Microdosing involves administering lower doses of testosterone esters or other injectable AAS over extended periods. Research suggests that this approach minimizes cardiovascular strain and liver toxicity while preserving anabolic outcomes. However, long-term data on microdosing efficacy and safety remain limited (43, 44).l

4. Health Risks of Anabolic Steroid Use: -

1. Cardiovascular Risks

One of the most significant and well-documented risks of AAS use is cardiovascular disease. AAS have been shown to negatively affect lipid profiles, increasing low-density lipoprotein (LDL) cholesterol and decreasing high-density lipoprotein (HDL) cholesterol, both of which contribute to the development of atherosclerosis and cardiovascular diseases. Studies indicate that AAS use also leads to increased blood pressure and alterations in the coagulation system, further increasing the risk of myocardial infarction, stroke, and other cardiovascular events (45, 46). The risk is particularly heightened when AAS are used in high doses or for prolonged periods, and when combined with other substances, such as stimulants.

2. Hepatotoxicity

Another major health risk associated with AAS use is hepatotoxicity, particularly with oral steroids such as oxymetholone, stanozolol, and methandrostenolone. These compounds undergo hepatic metabolism, which can lead to liver damage, including liver dysfunction, liver cancer, and peliosis hepatis (formation of blood-filled cysts in the liver). A 2023 study highlighted the severe hepatotoxic effects of prolonged AAS use, with some users experiencing liver enzyme alterations and significant liver damage (47, 48). The risk is especially concerning when AAS are used without medical supervision or when they are abused in high doses.

3. Endocrine Disruptions

The endocrine system is highly sensitive to the hormonal changes induced by AAS use. One of the primary concerns is the suppression of the hypothalamic-pituitary-gonadal (HPG) axis, leading to decreased endogenous testosterone production. This suppression can result in testicular atrophy, reduced sperm production, and infertility. Additionally, the use of AAS is linked to the development of gynecomastia (breast tissue enlargement in men) due to the

aromatization of testosterone to estrogen. These endocrine disruptions can have long-lasting effects on reproductive health and sexual function (49, 50).

4. Psychological and Behavioral Effects

The use of AAS is also associated with significant psychological and behavioral effects. AAS can alter mood, leading to irritability, aggression, anxiety, and depression, a phenomenon commonly referred to as "roid rage." Long-term AAS use is linked to cognitive impairments and psychiatric disorders, including mania, paranoia, and psychosis. These psychological effects are particularly concerning because they may contribute to risky behaviors, including violence and substance abuse (51, 52). A 2024 study found that the psychological disturbances associated with AAS use were exacerbated by high-dose regimens, emphasizing the importance of regulating AAS usage to mitigate these effects (53).

5. Reproductive Health Risks

The reproductive system is also severely impacted by AAS use, particularly in males. Testicular atrophy, a common **con**sequence of AAS abuse, can lead to irreversible infertility in some individuals. A study conducted in 2023 demonstrated that long-term AAS users experienced a significant reduction in sperm count and motility, with many showing symptoms of hypogonadism even after discontinuing steroid use (54). Additionally, AAS use can cause erectile dysfunction and loss of libido due to hormonal imbalances. These effects highlight the need for comprehensive education on the reproductive risks of AAS.

6. Musculoskeletal Injuries

While AAS can increase muscle mass and strength, they may also lead to musculoskeletal injuries. Rapid muscle growth, especially without a proportional increase in tendon and ligament strength, can result in tendonitis, ligament strains, and other musculoskeletal injuries. A study in 2023 found that AAS users, particularly those in strength sports, were at an increased risk of tendon injuries due to the disproportionate growth of muscle fibers compared to connective tissue (55). Moreover, AAS use may cause premature closure of growth plates in adolescents, potentially leading to stunted growth (56).

7. Psychosocial Impacts and Social Stigma

The psychosocial impact of AAS use is also significant. Athletes and bodybuilders who use AAS often experience social stigma, which can lead to issues with self-esteem and social isolation. Additionally, the psychological dependence on AAS can lead to an addiction-like syndrome known as anabolic steroid dependence (ASD). Users may prioritize steroid use over other aspects of life, leading to personal and social consequences such as relationship problems and career setbacks (57). Studies suggest that AAS dependence is more common in individuals with a history of mental health disorders, underscoring the need for targeted interventions in these populations (58).

5. Conclusion

The use of anabolic-androgenic steroids (AAS) presents significant health risks, despite their appeal for enhancing athletic performance and muscle growth. While AAS can provide benefits such as increased muscle mass, strength, and improved recovery, the adverse effects associated with their use are undeniable and multifaceted. Cardiovascular complications, hepatotoxicity, endocrine disruptions, psychological disturbances, reproductive health risks, and musculoskeletal injuries are all well-documented consequences of AAS abuse. These risks are amplified by prolonged use, high doses, and inadequate post-cycle therapy, which can lead to long-term health complications, including infertility, cardiovascular diseases, and psychological disorders.

Furthermore, the social and psychological impacts of AAS use, such as dependence, aggression, and stigma, create significant challenges for individuals and society. Despite efforts by sports organizations to regulate and prohibit AAS, their misuse remains prevalent, fueled by the pressures of performance enhancement and body image ideals. Comprehensive education, stricter regulations, and increased awareness of the long-term health consequences are crucial to addressing the widespread misuse of AAS. Athletes, especially, must be made aware of the risks associated with AAS use and the potential for irreversible damage to their health. As the global trend of AAS use continues, ongoing research is essential to better understand the full spectrum of risks and to develop strategies for effective prevention and intervention.

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