International Journal of Basic & Clinical Pharmacology
Balakrishnan YS. Int J Basic Clin Pharmacol. 2026 Sep;15(5):1095-1102
https://www.ijbcp.com
pISSN 2319-2003 | eISSN 2279-0780

DOI: https://dx.doi.org/10.18203/2319-2003.ijbcp20262886

Review Article

Enhancement or endangerment: a narrative review of pharmacological agents used in the fitness industry

Yogesh Shergin Balakrishnan*

Department of Pharmacology, Grant Government Medical college, Mumbai, Maharashtra, India

Received: 10 June 2026
Accepted: 10 July 2026

***Correspondence:**
Dr. Yogesh Shergin Balakrishnan,
Email: yogeshshergin96@gmail.com

ABSTRACT

The global fitness industry has witnessed a significant rise in the use of pharmacological agents for enhancement of muscle mass, athletic performance, fat reduction, and physical appearance. Even though regular exercise and balanced nutrition remain the cornerstone of fitness, increasing societal pressure for rapid aesthetic transformation has contributed to the misuse of performance-enhancing drugs (PEDs). This narrative review aims to provide a comprehensive overview of the major pharmacological agents currently used in the fitness industry, including anabolic-androgenic steroids (AAS), selective androgen receptor modulators (SARMs), growth hormone and peptide analogues, stimulants, fat burners, insulin, thyroid hormones, diuretics, and post-cycle therapy drugs. A literature search was conducted using PubMed, Scopus, and Google Scholar databases using relevant keywords related to performance enhancement and fitness pharmacology. Recent evidence from clinical studies, systematic reviews, and regulatory reports were included. Advantages such as increased lean muscle mass, enhanced recovery, improved endurance, and accelerated fat loss were offered by these agents. However, their misuse is associated with serious cardiovascular, endocrine, hepatic, renal, neuropsychiatric, and metabolic complications. The emergence of social media promotion and unregulated online markets has further increased accessibility and misuse, especially among young adults. World anti-doping agency (WADA) and the United States Food and Drug Administration (FDA) continue to issue warnings regarding the safety concerns associated with these substances. This review highlights the pharmacology, benefits, adverse effects, ethical concerns, and public health implications of pharmacological agents used in the fitness industry, emphasizing the urgent need for awareness, regulation, and evidence-based education.

Keywords: Performance enhancing drugs, Physical fitness, Drug misuse, Doping, Sports medicine

INTRODUCTION

The pursuit of physical fitness and aesthetic perfection has increased substantially in recent years due to changing standards of society, increased awareness regarding physical appearance, and the influence of social media platforms. Physical appearance, body image, and anthropometric characteristics such as weight, body fat percentage, and muscularity are increasingly linked with self-esteem and social acceptance. Unrealistic body standards propagated through digital media have contributed to body dissatisfaction, depression, anxiety, eating disorders, and body dysmorphic disorders among adolescents and young adults.[1] Consequently, many individuals resort to pharmacological agents to accelerate muscle growth, reduce body fat, improve endurance, or enhance athletic performance.[2]

While structured exercise programs, balanced nutrition, and lifestyle modifications remain the ideal methods for achieving fitness goals, there has been a growing tendency among athletes and recreational gym users to seek rapid improvements through pharmacological enhancement. This trend has contributed to the widespread use of PEDs within the fitness industry.[3]

Historically, the use of performance-enhancing substances were used by ancient Greek athletes who reportedly consumed herbal stimulants and excessive amounts of meat to improve performance during Olympic events.[4] Roman gladiators used substances such as strychnine to reduce fatigue and improve combat endurance. In the 1950s, testosterone injections were reportedly administered to Soviet weightlifters to improve strength and athletic performance. The 1988 Seoul Olympics marked a turning point in anti-doping awareness when sprinter Ben Johnson was stripped of his gold medal after testing positive for stanozolol.[5] During the twentieth century, the use of anabolic steroids became increasingly prevalent among professional athletes.[4,5]

The modern fitness industry now includes a wide range of pharmacological agents beyond traditional anabolic steroids. These include SARMs, peptide hormones, growth hormone analogues, stimulants, beta-2 agonists, insulin, thyroid hormones, and diuretics. Although some of these agents possess legitimate therapeutic indications approved by FDA, their off-label use for physique enhancement and athletic performance is associated with multiple adverse effects affecting nearly every organ system.[6,7]

The increasing prevalence of PED use among non-elite athletes, adolescents, and amateur bodybuilders represents a major public health concern.[8] The availability of these substances through online markets, social media promotion, and unregulated supplement industries has further complicated regulatory control. Moreover, misinformation regarding the safety and efficacy of these agents often leads users to underestimate their harmful effects.[2,8]

This narrative review aims to provide a comprehensive overview of the major pharmacological agents used in the fitness industry, with emphasis on their pharmacological mechanisms, perceived benefits, adverse effects, legal status, and public health implications. The review also highlights ethical and regulatory challenges associated with the growing misuse of these substances.

LITERATURE SEARCH

A comprehensive literature search was conducted using electronic databases including PubMed, Scopus, Google Scholar, and Web of Science to identify relevant studies related to pharmacological agents used for performance enhancement in the fitness industry. Keywords used during the search included "performance-enhancing drugs," "anabolic steroids," "SARMs," "growth hormone," "bodybuilding," "sports pharmacology," "fat burners," "doping," and "fitness industry."

Relevant randomized controlled trials, systematic reviews, meta-analyses, observational studies, narrative reviews, regulatory reports, and case studies published were included. Additional references were obtained through cross-referencing of selected articles. Only pharmacological agents specifically used for enhancement of athletic performance, muscle mass, endurance, or physique modification were considered. Dietary supplements, herbal products, and non-pharmacological interventions were excluded from this review. Data were extracted and organized according to drug class, mechanism of action, therapeutic indications, performance-enhancing effects, adverse effects, and regulatory status.

Since this review utilized information from publicly available published literature, institutional ethics committee approval was not required.

PHARMACOLOGICAL AGENTS USED IN THE FITNESS INDUSTRY

AAS

AAS are synthetic derivatives of testosterone designed to maximize anabolic effects such as muscle growth while minimizing androgenic effects. They are the most commonly abused pharmacological agents in bodybuilding and strength-based sports.[9] Commonly used agents include testosterone esters, nandrolone, stanozolol, methandrostenolone, oxandrolone, trenbolone, and oxymetholone.[10]

AAS exert their effects primarily through activation of intracellular androgen receptors. Following receptor binding, the steroid-receptor complex translocates into the nucleus and regulates transcription of genes involved in protein synthesis and muscle hypertrophy. These agents also increase nitrogen retention, satellite cell proliferation, erythropoiesis, and inhibition of catabolic glucocorticoid pathways.[11,12] The perceived ergogenic advantages of AAS include increased lean muscle mass, enhanced protein synthesis, improved recovery after exercise, increased strength and power output, reduced exercise-induced muscle damage, enhanced erythropoiesis and endurance. Many users employ "stacking" strategy involving multiple steroids simultaneously or "cycling" regimens to maximize effects while attempting to reduce toxicity.[11,13]

Despite their performance-enhancing effects, AASs are associated with significant adverse effects. Cardiovascular adverse effects such as hypertension, dyslipidaemia, atherosclerosis, arrhythmias, cardiomyopathy, myocardial infarction and sudden cardiac death. Endocrine/reproductive adverse effects such as testicular atrophy, infertility, gynecomastia, erectile dysfunction, hypogonadism. The hepatic adverse effects include hepatotoxicity, cholestatic jaundice, peliosis hepatis, hepatic tumors. The Neuropsychiatric adverse effects include aggression, anxiety, depression, insomnia, dependence. The dermatological adverse effects such as acne, seborrhoea, alopecia, striae were also seen. In

Women ,virilization, hirsutism, deepened voice, menstrual disturbances, clitoromegaly were observed.[14]

SARMs

SARMs are non-steroidal compounds that selectively stimulate androgen receptors in skeletal muscle and bone while minimizing androgenic effects on reproductive tissues. Commonly used SARMs include ostarine , ligandrol, andarine, testolone, and cardarine.[15]

SARMs selectively bind androgen receptors and induce anabolic signaling pathways responsible for muscle growth and bone density enhancement. Unlike anabolic steroids, they exhibit tissue selective activity and produce fewer androgenic adverse effects. SARMs are commonly promoted for their ability to increase lean body mass, enhance muscle strength, improve bone mineral density, and accelerate recovery after training. They are also often marketed as having a lower incidence of androgenic adverse effects when compared to traditional anabolic steroids.[16,17]

However, despite being advertised as safer alternatives to anabolic steroids, SARMs have been associated with several adverse effects. Reported adverse events include hepatotoxicity, cholestatic jaundice, suppression of endogenous testosterone production, infertility, mood disturbances, increased cardiovascular risk, sleep disturbances, acne, and hair loss. In addition, several case reports and clinical observations have documented severe liver injury associated with the recreational use of SARMs. Currently, no SARM has received approval for recreational bodybuilding use. These agents are banned by the WADA. Many commercially available products are contaminated, inaccurately labelled, or illegally marketed as dietary supplements.[11]

Growth hormone and peptides

Growth hormone (GH) and peptide hormones are widely abused in bodybuilding due to their anabolic and lipolytic effects. Common agents include recombinant human growth hormone (HGH), insulin-like growth factor-1 (IGF-1), growth hormone releasing peptides (GHRPs).[18]

Growth hormone stimulates hepatic production of IGF-1, which promotes protein synthesis, skeletal muscle growth, and lipolysis. Peptide hormones stimulate endogenous GH release through hypothalamic and pituitary pathways. These agents are commonly promoted for their potential to increase lean body mass, reduce body fat percentage, improve connective tissue healing, and enhance recovery following exercise. They are also claimed to possess anti-aging properties and to improve skin texture and overall appearance.[19]

Despite these benefits, their use has been associated with several adverse effects such as edema and fluid retention, arthralgia, myalgia, insulin resistance leading to diabetes mellitus, and carpal tunnel syndrome. More serious adverse effects such as cardiomyopathy, acromegaly with chronic abuse, and an increased risk of malignancy have also been reported.[20-23]

Stimulants and fat burners

Stimulants and fat-burning agents are frequently used during “cutting cycles” to enhance energy expenditure and reduce body fat. Commonly used agents include caffeine, ephedrine, synephrine, clenbuterol, yohimbine, and amphetamine derivatives.[24]

Most stimulants increase sympathetic nervous system activity through catecholamine release or beta-adrenergic receptor stimulation. This leads to increased thermogenesis, lipolysis, alertness, and metabolic rate. These substances are commonly claimed to increase energy levels, reduce fatigue, enhance focus and concentration, suppress appetite, promote lipolysis, and improve exercise endurance. Because of these perceived benefits, they are frequently misused for weight loss and performance enhancement purposes.

However, their use is associated with several significant adverse effects such as hypertension, tachycardia, cardiac arrhythmias, anxiety, panic attacks, insomnia, and hyperthermia. Severe cardiovascular events such as stroke and myocardial infarction have also been reported. Despite being prohibited for use in several countries, clenbuterol abuse has become increasingly popular among bodybuilders and individuals seeking rapid fat loss.[25-28]

Insulin and thyroid hormones

Insulin and thyroid hormones are frequently misused by bodybuilders during bulking and cutting cycles. Insulin is used for its anabolic properties, including increased glycogen synthesis and amino acid uptake into skeletal muscle.[29]

These agents are commonly used for their claimed ability to increase muscle glycogen storage, enhance nutrient partitioning, promote muscle growth, and improve recovery following intense physical activity. Because of these perceived anabolic effects, they are sometimes misused by athletes and bodybuilders.[30]

However, their misuse can result in serious and potentially life-threatening adverse effects. Reported complications include severe hypoglycemia, weight gain, and the development of insulin resistance. In more severe cases, hypoglycemia may lead to seizures, coma, and even sudden death.[31]

Thyroid hormones

Triiodothyronine (T3) and thyroxine (T4) are abused for rapid fat loss due to their metabolic effects.

These agents are commonly used for their ability to increase metabolic rate, accelerate fat loss, and reduce body fat percentage. As result, they are frequently misused for rapid weight reduction and physique enhancement.[32]

However, their use is associated with several adverse effects such as muscle wasting, tachycardia, cardiac arrhythmias, osteoporosis, thyroid suppression, anxiety, and tremors. Prolonged or excessive use may lead to serious metabolic and cardiovascular complications.[30]

Diuretics

Diuretics are commonly abused before bodybuilding competitions to reduce subcutaneous water retention and improve muscular definition. Common agents include furosemide, hydrochlorothiazide, spironolactone, and bumetanide. These drugs increase renal excretion of sodium and water, thereby reducing extracellular fluid volume. These agents are commonly used for their ability to temporarily reduce body water, improve muscle definition, and facilitate rapid weight reduction before competitions. They are also misused to mask the presence of other prohibited substances during urine testing.[33]

However, their use is associated with several serious adverse effects such as severe dehydration, electrolyte imbalance, hypokalemia, cardiac arrhythmias, and acute kidney injury. Users have also reported muscle cramps, weakness, and other complications related to fluid and electrolyte loss.[34,35]

Post-cycle therapy (PCT) drugs

PCT refers to the use of medications intended to restore endogenous testosterone production following anabolic steroid cycles. AAS use suppresses endogenous luteinizing hormone (LH) mediated testosterone production, which may persist for many months to years after cessation.[36-39] Men experiencing AAS-induced central hypogonadism may report physical and neuropsychiatric symptoms, including weakness, reduced libido, erectile dysfunction, depression, anxiety, and suicidality.[40,41] Men who use AAS often adopt various strategies to minimize the symptoms of hypogonadism associated with steroid withdrawal. One common method is the "blast and cruise" approach, in which high doses of AAS are used for a period which is referred as "blast", followed by prolonged use of lower maintenance doses refereed as "cruise". Another strategy is "cycling," where individuals use AAS for a defined period, typically 6-12 weeks called "on-cycle", followed by an "off-cycle" phase during which they discontinue AAS and may use PCT to help restore endogenous hormone production and reduce withdrawal-related symptoms.[42,43] PCT is a non-medical term used to describe a varied group of self-administered substances, either with the aim to limit the adverse effects of AAS use between AAS cycles or to accelerate recovery of endogenous hypothalamic pituitary gonadal (HPG) axis function after permanent AAS cessation.[44,45]

Various PCT regimes have been reported but typically involve the use of human chorionic gonadotrophin (hCG) in combination with selective estrogen receptor modulators (SERM) and/or aromatase inhibitors (AI). hCG directly stimulates testicular testosterone production within Leydig cells, while SERMs and AIs indirectly stimulate LH-mediated testosterone production and follicle-stimulating hormone (FSH)-mediated maintenance of seminiferous tubule mass by reducing the estrogenic negative feedback on the HPG axis. By restoring endogenous testosterone production quicker, men hope to minimize the symptoms of AAS induced hypogonadism and thus avoid some of the negative health effects of AAS use. Commonly used drugs include tamoxifen, clomiphene citrate, hCG, and aromatase inhibitors such as anastrozole and letrozole. These agents are commonly used for their claimed ability to restore endogenous testosterone production, reduce the risk of gynecomastia, improve recovery of fertility, and prevent estrogen related adverse effects. They are frequently utilized during post-cycle therapy following anabolic steroid use.

However, their use has been associated with several adverse effects such as visual disturbances, mood swings, thromboembolic events, reduced bone mineral density, and hormonal imbalance. Improper or prolonged use may further disrupt the normal endocrine system and lead to additional health complications.[46]

Table 1: Major pharmacological agents used in the fitness industry.

Drug classes	Common examples	Main purpose	Major risks
AAS	Testosterone, nandrolone	Muscle growth	Cardiovascular and endocrine toxicity
SARMs	Ostarine, ligandrol	Lean muscle gain	Hepatotoxicity
Growth hormone	HGH, IGF-1	Recovery and fat loss	Diabetes and acromegaly
Stimulants	Clenbuterol, Ephedrine	Fat loss and energy	Arrhythmias
Insulin	Rapid-acting insulin	Anabolic enhancement	Hypoglycemia
Thyroid hormones	T3, T4	Fat loss	Muscle wasting
Diuretics	Furosemide	Water loss	Dehydration

ETHICAL, LEGAL AND REGULATORY ASPECTS

The use of pharmacological agents for performance enhancement raises significant ethical and legal concerns in sports and public health.[11,47,48] The WADA maintains a list of prohibited substances and methods that are banned in competitive sports. Athletes found using these substances may face suspension, disqualification, reputational damage, and legal penalties. Despite strict regulations, black market availability and online marketing continue to facilitate access to PEDs.[49,50] In India, anti-doping activities are regulated by the National Anti-Doping Agency (NADA), which implements the National Anti-Doping Rules, 2021 governing sample collection, result management, and disciplinary proceedings.[51]

Many products sold online are counterfeit, contaminated, or inaccurately labelled. Social media influencers frequently promote these substances without adequate disclosure regarding their risks.[2,50] Strict regulations has to be framed to look into all the mis information regarding the performance enhancing drugs that is available on social media. The misuse of prescription medications such as testosterone, growth hormone, insulin, and thyroid hormones without medical supervision also represents a major issue in clinical practice. Healthcare professionals play an important role in identifying misuse, counselling patients, and reporting adverse drug reactions.[52] Strengthening awareness among healthcare providers regarding the recognition and management of PEDs use should be considered.

PUBLIC HEALTH IMPLICATIONS

The increasing prevalence of PED use among adolescents, recreational bodybuilders, and amateur athletes represents a growing public health concern.[53,54] Easy accessibility through online markets and misinformation on social media platforms have normalized the use of these substances among young individuals.[3,50] Long-term use of PEDs may lead to irreversible cardiovascular, hepatic, endocrine, renal, and psychiatric complications.[55-57] Additionally, dependence syndromes and body image disorders contribute to persistent misuse.[58] In this social media era, lot of young people are easily influenced by influencers on social media and try to follow their advices without thorough research. So, educational interventions, improved doping surveillance, and awareness campaigns are essential to reduce the burden of pharmacological misuse in the fitness industry.[12,59] Pharmacologists, sports medicine specialists, psychiatrists, endocrinologists, and public health authorities must work collaboratively to address this issue.

FUTURE DIRECTIONS

The growing use of pharmacological agents for physique enhancement, performance optimization, and weight management highlights the need for a multidisciplinary approach involving researchers, clinicians, regulatory authorities, fitness professionals, and public health agencies. The emergence of novel compounds marketed through online platforms presents additional challenges.[60] Many products are sold as dietary supplements or research chemicals despite containing unapproved pharmacologically active substances. Strengthening regulatory oversight, improving product quality testing, and implementing stricter monitoring of online sales are essential to reduce exposure to counterfeit and adulterated products.[61,62]

Recent advances in obesity pharmacotherapy have been driven by incretin-based agents targeting glucagon-like peptide-1 (GLP-1), glucose-dependent insulinotropic polypeptide (GIP), and glucagon receptors. While semaglutide and tirzepatide have already demonstrated substantial efficacy in weight reduction, several next-generation agents are currently in development and are expected to further transform obesity management. The rapid rise in the popularity of GLP-1 and GIP-based therapies has extended beyond traditional obesity treatment settings.[63] Their increasing visibility on social media, endorsement by celebrities, and demand for cosmetic weight loss have contributed to widespread off-label use among individuals without clear medical indications. Despite their impressive efficacy, these agents are associated with several adverse effects. Such as gastrointestinal, including nausea, vomiting, diarrhea, constipation, abdominal discomfort, and dyspepsia. Most adverse effects are dose-dependent and occur during dose escalation. Rare but potentially serious adverse events include pancreatitis, gallbladder disease, acute kidney injury, and excessive loss of lean body mass. Future research should also focus on evaluating the long term cardiovascular, metabolic, and musculoskeletal outcomes of these therapies.[64-66]

Ultimately, future efforts should aim to balance the pursuit of physical enhancement with the principles of patient safety, ethical practice, and public health, ensuring that the benefits of pharmacological interventions do not outweigh their potential risks

CONCLUSION

Pharmacological agents used in the fitness industry may provide short-term benefits such as increased muscle mass, reduced body fat, enhanced recovery, and improved endurance but their misuse is associated with serious and potentially life-threatening adverse effects. Anabolic androgenic steroids remain the most commonly abused agents, while newer compounds such as SARMs and peptide hormones are increasingly being marketed as safer alternatives despite limited safety evidence. Stimulants, thyroid hormones, insulin, and diuretics further contribute to the growing complexity of pharmacological enhancement practices. The influence of social media, unregulated online markets, and misinformation has significantly contributed to the widespread misuse of these

substances. Comprehensive educational strategies, stronger regulatory frameworks, early identification of misuse, and multidisciplinary healthcare approaches are essential to address the public health challenges associated with pharmacological enhancement in the fitness industry.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: Not required

REFERENCES

1. Mironica A, Popescu CA, George D, Tegzeșiu AM, Gherman CD. Social media influence on body image and cosmetic surgery considerations: a systematic review. Cureus. 2024;16(7):10.
2. Merino M, Tornero-Aguilera JF, Rubio-Zarapuz A, Villanueva-Tobaldo CV, Martín-Rodríguez A, Clemente-Suárez VJ. Body perceptions and psychological well-being: a review of the impact of social media and physical measurements on self-esteem and mental health with a focus on body image satisfaction and its relationship with cultural and gender factors. In Healthcare. 2024;12(14):1396.
3. Horn J. The dichotomy between health and drug abuse in bodybuilding. Nord Alkohol-Nark NAT. 2024;41(2):212-25.
4. Dandoy C, Gereige RS. Performance-enhancing drugs. Pediat Rev. 2012;33(6):265-72.
5. Mackey TK, Liang BA, Strathdee SA. Digital social media, youth, and nonmedical use of prescription drugs: the need for reform. J Med Internet Res. 2013;15(7):e143.
6. Bowers LD. Athletic drug testing. Clin Sports Med. 1998;17(2):299-318.
7. Walsh G. Our drug happy athletes. Sports Illustrated. 1960;13(21):26-38.
8. Handelsman DJ. Performance enhancing hormone doping in sport. Endotext. 2025.
9. Yesalis CE, Kennedy NJ, Kopstein AN, Bahrke MS. Anabolic-androgenic steroid use in the United States. Jama. 1993;270(10):1217-21.
10. Piacentino D, Kotzalidis G, Casale A, Aromatario M, Pomara C, Girardi P, et al. Anabolic-androgenic steroid use and psychopathology in athletes. Curr Neuropharmacol. 2015;13(1):101-21.
11. Nieschlag E, Vorona E. Mechanisms in endocrinology: medical consequences of doping with anabolic androgenic steroids: effects on reproductive functions. Europ J Endocrinol. 2015;173(2):R47-58.
12. van Amsterdam J, Opperhuizen A, Hartgens F. Adverse health effects of anabolic-androgenic steroids. Regulatory Toxicol Pharmacol. 2010;57(1):117-23.
13. Kanayama G, Hudson JI, Pope Jr HG. Long-term psychiatric and medical consequences of anabolic-androgenic steroid abuse: A looming public health concern? Drug Alcohol Dependence. 2008;98(1-2):1-2.
14. Pope Jr HG, Wood RI, Rogol A, Nyberg F, Bowers L, Bhasin S. Adverse health consequences of performance-enhancing drugs: an Endocrine Society scientific statement. Endocrine Rev. 2014;35(3):341-75.
15. Solomon ZJ, Mirabal JR, Mazur DJ, Kohn TP, Lipshultz LI, Pastuszak AW. Selective Androgen Receptor Modulators: Current Knowledge and Clinical Applications. Sex Med Rev. 2019;7(1):84-94.
16. Dalton JT, Taylor RP, Mohler ML, Steiner MS. Selective androgen receptor modulators for the prevention and treatment of muscle wasting associated with cancer. Curr Opin Support Palliat Care. 2013;7(4):345-51.
17. Bhasin S, Krishnan V, Storer TW, Steiner M, Dobs AS. Androgens and Selective Androgen Receptor Modulators to Treat Functional Limitations Associated with Aging and Chronic Disease. J Gerontol A Biol Sci Med Sci. 2023;78(1):25-31.
18. Anderson LJ, Tamayose JM, Garcia JM. Use of growth hormone, IGF-I, and insulin for anabolic purpose: Pharmacological basis, methods of detection, and adverse effects. Mol Cell Endocrinol. 2018;464:65-74.
19. Hameed M, Lange KH, Andersen JL, Schjerling P, Kjaer M, Harridge SD, Goldspink G. The effect of recombinant human growth hormone and resistance training on IGF-I mRNA expression in the muscles of elderly men. J Physiol. 2004;555(Pt 1):231-40.
20. Götherström G, Elbornsson M, Stibrant-Sunnerhagen K, Bengtsson BA, Johannsson G, Svensson J. Ten years of growth hormone (GH) replacement normalizes muscle strength in GH-deficient adults. J Clin Endocrinol Metab. 2009;94(3):809-16.
21. Widdowson WM, Gibney J. The effect of growth hormone (GH) replacement on muscle strength in patients with GH-deficiency: a meta-analysis. Clin Endocrinol (Oxf). 2010;72(6):787-92.
22. Holt RI, Sönksen PH. Growth hormone, IGF-I and insulin and their abuse in sport. Br J Pharmacol. 2008;154(3):542-56.
23. Barroso O, Mazzoni I, Rabin O. Hormone abuse in sports: the antidoping perspective. Asian J Androl. 2008;10(3):391-402.
24. Woodgate DE, Conquer JA. Effects of a stimulant-free dietary supplement on body weight and fat loss in obese adults: a six-week exploratory study. Curr Ther Res Clin Exp. 2003;64(4):248-62.
25. Maughan RJ, Burke LM, Dvorak J, Larson-Meyer DE, Peeling P, Phillips SM, Rawson ES, Walsh NP, Garthe I, Geyer H, Meeusen R. IOC consensus statement: dietary supplements and the high-performance athlete. Int J Sport Nutrit Exercise Metabol. 2018;28(2):104-25.
26. Guest NS, VanDusseldorp TA, Nelson MT, Grgic J, Schoenfeld BJ, Jenkins ND, Arent SM, Antonio J, Stout JR, Trexler ET, Smith-Ryan AE. International society of sports nutrition position stand: caffeine and

exercise performance. J Int Society Sports Nutrit. 2021;18(1):1.
27. Hoffman RJ, Hoffman RS, Freyberg CL, Poppenga RH, Nelson LS. Clenbuterol ingestion causing prolonged tachycardia, hypokalemia, and hypophosphatemia with confirmation by quantitative levels. J Toxicol. 2001;39(4):339-44.
28. Pickering C, Grgic J. Caffeine and exercise: what next? Sports Med. 2019;49(7):1007-30.
29. Williams Textbook of Endocrinology. Melmed S, Auchus RJ, Goldfine AB, Koenig RJ, Rosen CJ, editors. Williams Textbook of Endocrinology. 14th ed. Philadelphia: Elsevier. 2020.
30. Gild ML, Stuart M, Clifton-Bligh RJ, Kinahan A, Handelsman DJ. Thyroid Hormone Abuse in Elite Sports: The Regulatory Challenge. J Clin Endocrinol Metab. 2022;107(9):e3562-73.
31. Sonksen PH. Hormones and Sport-Insulin, growth hormone and sport. J Endocrinol. 2001;170(1):13-26.
32. Salvatore D, Simonides WS, Dentice M, Zavacki AM, Larsen PR. Thyroid hormones and skeletal muscle--new insights and potential implications. Nat Rev Endocrinol. 2014;10(4):206-14.
33. Cadwallader AB, De La Torre X, Tieri A, Botrè F. The abuse of diuretics as performance-enhancing drugs and masking agents in sport doping: pharmacology, toxicology and analysis. Brit J Pharmacol. 2010;161(1):1-6.
34. Arumugham V, Shahin M. Therapeutic uses of diuretic agents. StatPearls. 2023.
35. Armstrong LE, Costill DL, Fink WJ. Influence of diuretic-induced dehydration on competitive running performance. Med Sci Sports Exerc. 1985;17(4):456-61.
36. Shankara-Narayana N, Yu C, Savkovic S, Desai R, Fennell C, Turner L, et al. Rate and extent of recovery from reproductive and cardiac dysfunction due to androgen abuse in men. J Clin Endocrinol Metabol. 2020;105(6):1827-39.
37. Kanayama G, Hudson JI, DeLuca J, Isaacs S, Baggish A, Weiner R, et al. Prolonged hypogonadism in males following withdrawal from anabolic–androgenic steroids: an under-recognized problem. Addiction. 2015;110(5):823-31.
38. Rasmussen JJ, Selmer C, Østergren PB, Pedersen KB, Schou M, Gustafsson F, et al. Former abusers of anabolic androgenic steroids exhibit decreased testosterone levels and hypogonadal symptoms years after cessation: a case-control study. PloS One. 2016;11(8):e0161208.
39. Smit DL, Buijs MM, De Hon O, Den Heijer M, De Ronde W. Disruption and recovery of testicular function during and after androgen abuse: the HAARLEM study. Human Reprod. 2021;36(4):880-90.
40. Pope Jr HG, Katz DL. Affective and psychotic symptoms associated with anabolic steroid use. Am J Psychiat. 1988;145(4):487-90.
41. Sharma A, Grant B, Islam H, Kapoor A, Pradeep A, Jayasena CN. Common symptoms associated with usage and cessation of anabolic androgenic steroids in men. Best Practice Res Clin Endocrinol Metabol. 2022;36(5):101691.
42. Cohen J, Collins R, Darkes J, Gwartney D. A league of their own: demographics, motivations and patterns of use of 1,955 male adult non-medical anabolic steroid users in the United States. J Int Society Sports Nutrit. 2007;4(1):12.
43. Karavolos S, Reynolds M, Panagiotopoulou N, McEleny K, Scally M, Quinton R. Male central hypogonadism secondary to exogenous androgens: a review of the drugs and protocols highlighted by the online community of users for prevention and/or mitigation of adverse effects. Clin Endocrinol. 2015;82(5):624-32.
44. Bonnecaze AK, O'Connor T, Aloi JA. Characteristics and attitudes of men using anabolic androgenic steroids (AAS): a survey of 2385 men. Am J Men's Health. 2020;14(6):1557988320966536.
45. Parkinson AB, Evans NA. Anabolic androgenic steroids: a survey of 500 users. Med Sci Sports Exercise. 2006;38(4):644-51.
46. de Ronde W, Smit DL. Anabolic androgenic steroid abuse in young males. Endocrine Connections. 2020;9(4):R102-11.
47. Van Amsterdam J, Opperhuizen A, Hartgens F. Adverse health effects of anabolic-androgenic steroids. Regulatory Toxicol Pharmacol. 2010;57(1):117-23.
48. Brennan BP, Kanayama G, Hudson JI, Pope, Jr HG. Human growth hormone abuse in male weightlifters. Am J Addictions. 2011;20(1):9-13.
49. Kanayama G, Brower KJ, Wood RI, Hudson JI, Pope Jr HG. Treatment of anabolic-androgenic steroid dependence: Emerging evidence and its implications. Drug Alcohol Dependence. 2010;109(1-3):6-13.
50. World Health Organization. Global status report on physical activity and health. Geneva: WHO; 2024.
51. Star S. The quest for harmonisation in anti-doping: an Indian perspective. Int Sports Law J. 2023;23(1):44-63.
52. El Osta R, Almont T, Diligent C, Hubert N, Eschwège P, Hubert J. Anabolic steroids abuse and male infertility. Basic Clin Androl. 2016;26(1):2.
53. Solomon ZJ, Mirabal JR, Mazur DJ, Kohn TP, Lipshultz LI, Pastuszak AW. Selective Androgen Receptor Modulators: Current Knowledge and Clinical Applications. Sex Med Rev. 2019;7(1):84-94.
54. Busardo F, Frati P, Di Sanzo M, Napoletano S, Pinchi E, Zaami S, Fineschi V. The impact of nandrolone decanoate on the central nervous system. Curr Neuropharmacol. 2015;13(1):122-31.
55. Yesalis CE, Kennedy NJ, Kopstein AN, Bahrke MS. Anabolic-androgenic steroid use in the U nited States. Jama. 1993;270(10):1217-21.
56. Piacentino D, D Kotzalidis G, Del Casale A, Rosaria Aromatario M, Pomara C, Girardi P, Sani G. Anabolic-androgenic steroid use and

psychopathology in athletes. A systematic review. Current Neuropharmacol. 2015;13(1):101-21.
57. Handelsman DJ, Hirschberg AL, Bermon S. Circulating Testosterone as the Hormonal Basis of Sex Differences in Athletic Performance. Endocr Rev. 2018;39(5):803-29.
58. Hildebrandt T, Harty S, Langenbucher JW. Fitness supplements as a gateway substance for anabolic-androgenic steroid use. Psychol Addict Behav. 2012;26(4):955-62.
59. Neri M, Bello S, Bonsignore A, Cantatore S, Riezzo I, Turillazzi E, Fineschi V. Anabolic androgenic steroids abuse and liver toxicity. Mini Rev Med Chem. 2011;11(5):430-7.
60. Tucker J, Fischer T, Upjohn L, Mazzera D, Kumar M. Unapproved pharmaceutical ingredients included in dietary supplements associated with US Food and Drug Administration warnings. JAMA network open. 2018;1(6):e183337.
61. Al-Saad N, Aljaal S, Alessa J, Santhosh ME. Systematic review of undeclared prohibited substances and pharmacological adulterants in dietary supplements: prevalence, detection, and risks in sport. Front Sports Active Living. 2026;8:1740663.
62. Van Wagoner RM, Eichner A, Bhasin S, Deuster PA, Eichner D. Chemical composition and labeling of substances marketed as selective androgen receptor modulators and sold via the internet. JAMA. 2017;318(20):2004-10.
63. Jastreboff AM, Kaplan LM, Hartman ML. Triple-hormone-receptor agonist retatrutide for obesity. N Eng J Med. 2023;389(17):1629-30.
64. Moiz A, Filion KB, Toutounchi H, Tsoukas MA, Yu OH, Peters TM, et al. Efficacy and safety of glucagon-like peptide-1 receptor agonists for weight loss among adults without diabetes: a systematic review of randomized controlled trials. Ann Internal Med. 2025;178(2):199-217.
65. Melson E, Ashraf U, Papamargaritis D, Davies MJ. What is the pipeline for future medications for obesity? Int Obesity. 2025;49(3):433-51.
66. Aronne LJ, Horn DB, le Roux CW, Ho W, Falcon BL, Gomez Valderas E, et al. Tirzepatide as compared with semaglutide for the treatment of obesity. N Engl J Med. 2025;393(1):26-36.

Cite this article as: Balakrishnan YS. Enhancement or endangerment-a narrative review of pharmacological agents used in the fitness industry. Int J Basic Clin Pharmacol 2026;15:1095-102.