

Overview of counterfeiting in performance-enhancing drugs used in enhanced bodybuilding

Panorama de la falsificación en los fármacos potenciadores del rendimiento utilizados en el fisicoculturismo potenciado

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ABSTRACT

Performance-enhancing drugs encompass a wide and ever-evolving range of substances used to improve athletic performance and physical appearance; all of these substances are banned in competitive sports by the World Anti-Doping Agency. These products are often obtained from the black market, where counterfeits are easy to find because they are manufactured below the appropriate standards for pharmaceutical products. The objective of this review is to provide an overview of the counterfeiting of certain pharmacological substances used to increase muscle mass in order to warn consumers, athletes, coaches, and other sports science professionals. The main findings show that the counterfeiting of some performance-enhancing drugs is prevalent internationally, making it necessary to conduct studies to detect and evaluate counterfeit products, as well as take actions to raise awareness about the implications of their use.

Keywords: Anabolic androgenic steroids, selective androgen receptor modulators, banned substances, unapproved pharmaceuticals, counterfeit drugs.

RESUMEN

Los fármacos potenciadores del rendimiento abarcan una amplia gama de sustancias en constante evolución que se utilizan para mejorar el rendimiento deportivo y la apariencia física; todas estas sustancias están prohibidas en el deporte competitivo por la Agencia Mundial Antidopaje. Estos productos suelen obtenerse en el mercado negro donde es fácil encontrar falsificaciones ya que estos son manufacturados sin los estándares adecuados para productos farmacéuticos. El objetivo de esta revisión es ofrecer un panorama general de la falsificación de ciertas sustancias farmacológicas utilizadas con el objetivo de incrementar la masa muscular para advertir a los consumidores, atletas, entrenadores y otros profesionales de las ciencias del deporte. Los principales hallazgos exponen que la falsificación de algunos fármacos potenciadores del rendimiento es una situación prevalente a nivel internacional por lo que es necesario realizar estudios para la detección y evaluación de productos falsificados, así como acciones para advertir sobre las implicaciones que conlleva su uso.

Palabras clave: Esteroides androgénicos anabolizantes, moduladores selectivos del receptor de andrógenos, sustancias prohibidas, sustancias farmacológicas no aprobadas, falsificación de fármacos.

INTRODUCTION

Ergogenic aids include nutritional, pharmacological, physiological, psychological, and mechanical/biomechanical methods and strategies to improve work capacity, enhance athletic performance, and promote training adaptations. Pharmacological ergogenic aids involve a range of active pharmaceutical ingredients that can effectively enhance performance; however, their use also poses risks to both the athlete's athletic career and health (Guimarães-Ferreira *et al.*, 2019). These substances, often referred to as "performance-enhancing drugs," "performance and image-enhancing drugs," or "appearance-enhancing drugs," include a wide range of products such as anabolic agents, peptide hormones, growth factors, metabolic modulators, and other drugs that alter bodily functions to promote muscle growth, enhance physical performance, reduce body fat, and promote weight loss (Mooney *et al.*, 2017; Giorgetti *et al.*, 2022).

According to the World Anti-Doping Agency (WADA), the most common anti-doping rule violation among athletes is the use of prohibited substances or methods to enhance performance (Hurst *et al.*, 2019). For a substance or method to be considered prohibited in or out of competition, two key criteria are assessed based on medical or scientific evidence, including pharmacological effects or documented experience demonstrating that these substances, alone or in combination with other ingredients or methods, can enhance performance or pose a potential risk to the athlete's health (Heuberger and Cohen, 2019). Anabolic agents, particularly anabolic androgenic steroids (AAS), have been frequently detected, accounting for up to 50% of doping cases, as reported by WADA-accredited laboratories through the Anti-Doping Administration and Management System (ADAMS). This makes AAS the most common performance-enhancing drugs among anabolic agents (Geyer *et al.*, 2014). Non-therapeutic use of AAS has become widespread worldwide and is recognized as a growing substance use disorder,

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representing a significant public health challenge (McVeigh *et al.*, 2021). Despite this, the use and abuse of AAS and other substances to increase muscle mass is mistakenly believed to be primarily a problem among professional athletes trying to enhance athletic performance; however, in recent years, a larger group of users of these products are fitness enthusiasts at different levels of competition, as well as at a recreational level with different age ranges (Bhasin *et al.*, 2021; Barrios *et al.*, 2025), even including teenagers (LaBotz *et al.*, 2016). A key reason as to why individuals begin to consume drugs to build muscle mass and enhance their image is closely related to the rise of bodybuilding and fitness culture. This culture includes a subculture focused on enhanced physique, where various pharmacological substances are used in conjunction with nutritional and training methods and techniques to achieve a specific, often extreme, body ideal (Andreasson and Johansson, 2019; Henning and Andreasson, 2022).

Competitive bodybuilding is a physique sport that involves a rigorous preparation process that includes resistance training to build muscle mass, followed by efforts to reduce body fat and preserve lean mass (Helms *et al.*, 2019). During competitions, judges evaluate the overall physical appearance of athletes in various categories through mandatory poses in sequential order, considering factors such as proportion, symmetry, muscle size and quality (including density, separation, and definition), and skin tone (International Fitness and Bodybuilding Federation, 2024).

To achieve significant muscle gains, gym-goers and enhanced bodybuilders, along with strict diets and training routines, utilize anabolic agents combined with a complex and constantly evolving regimen of complementary drugs. This approach, known as “stacking”, is primarily based on experimental practices among pioneering bodybuilders and influential figures in the bodybuilding community (McVeigh *et al.*, 2021). In addition, ancillary drugs are used to mitigate the side effects of AAS use, such as antiestrogenic, cardiovascular, diuretic, and sexual performance agents. Substances such as weight-loss drugs, nonsteroidal analgesics, anti-inflammatory drugs, central nervous system depressants and stimulants, and other hormonal and non-hormonal agents are also commonly consumed (Sagoe *et al.*, 2015). With the cessation of AAS use comes post-cycle therapy (PCT). This term refers to drugs taken after discontinuing AAS use to reduce adverse effects on the hormonal system. The most commonly used products in this type of unapproved therapy are selective estrogen receptor modulators (SERMs), aromatase inhibitors, and preparations containing human chorionic gonadotropin, substances banned in sports by WADA (Blazewicz *et al.*, 2025). Consumers of all these products typically purchase them through websites, social media, and online marketplaces, believing they are buying genuine pharmaceuticals from reputable companies, unaware that these products do not meet adequate manufacturing standards (Fabresse *et al.*, 2021).

This article is not intended to be an exhaustive review of the scientific literature on analytical methods, but rather to

highlight the problem of counterfeiting some performance-enhancing drugs used for muscle mass gain, warning consumers, athletes, coaches, and sports science professionals about this persistent problem.

Anabolic androgenic steroids

Anabolic steroids are more accurately known as anabolic androgenic steroids, as they produce two effects: an anabolic effect (stimulation of protein synthesis to build muscle mass) and an androgenic effect (promoting masculinization). These substances are also known in slang by common names such as “roids,” “juice,” “gym candy,” and “pumpers” (Milhorn, 2018). A common misconception is that all steroids are used to increase muscle mass, but this is not always the case. Steroids are biomolecules involved in a wide range of physiological processes, such as the regulation of metabolism and immune response (glucocorticoids), maintenance of blood volume, and renal control of electrolyte excretion (mineralocorticoids) in vertebrates (Baker, 2019). There are four main classes of naturally occurring steroid hormones: androgens, corticosteroids, estrogens, and progestins (Barceloux and Palmer, 2013).

AAS are a group of diverse compounds that include both naturally occurring androgens, and their synthetic variants, which are created artificially in a laboratory setting. Testosterone is the primary endogenous hormone belonging to this class, and its esterified forms have been widely used as replacement therapy for the treatment of male hypogonadism. In addition to testosterone esters, a select few other AAS, such as nandrolone and oxandrolone, might also be prescribed for other medical conditions where muscle mass loss occurs (Bond *et al.*, 2022). Testosterone has been the basis of all synthetic AAS, with chemical modifications to improve its anabolic properties, bioavailability, and duration of action, while attempting to reduce androgenic effects. Consequently, intramuscular and oral formulations are available, with oral versions being less potent and more toxic than injectable products (Barceloux and Palmer, 2013). For this reason, steroid esters are often preferred, as they allow for a slower release of the active ingredient from the injection site for periods of up to four weeks (Fabresse *et al.*, 2021).

Although AAS are approved and developed as active pharmaceutical ingredients for therapeutic use in humans, some of these compounds have not been approved because they have not undergone the necessary clinical or preclinical evaluation processes. Despite this, they have been marketed and used, including those intended solely for veterinary purposes, as well as designer steroids. These unapproved substances are commonly found on the black market without official registration (Weber *et al.*, 2017).

Approved injectable AAS products for pharmacotherapy have different doses, with presentations ranging up to 250 mg of active pharmaceutical ingredient per milliliter, which are administered as a single dose at different intervals, from one to several weeks apart; in the case of oral products, these contain doses up to 25 mg in each tablet (Basaria *et*

al., 2001). The doses available in each formulation of these products can vary significantly by country, influenced by national regulations, prescribing guidelines, and commercial availability (Gooren *et al.*, 2007).

The use of AAS outside of medical contexts first gained traction in professional sports, particularly among bodybuilders (Mullen *et al.*, 2020), with prevalence rates ranging from 33.3% to 79.5% in this population (Bhasin *et al.*, 2021). The pattern of AAS abuse among athletes varies greatly, including differences in dose and duration of use. Among bodybuilders, patterns of use are more extreme, with self-medication and polypharmacy being prevalent. Typically, AAS use occurs in cycles lasting 6 to 12 weeks ("on cycle"), followed by periods of abstinence ("off cycle") to mitigate potential side effects. During these cycles, users typically start with low doses, gradually increasing to a peak at the end of the cycle (known as "pyramidal regimen"). Many users combine multiple steroids, either intramuscularly or orally, or use them in overlapping patterns to avoid the development of tolerance (referred to as "plateauing"). AAS dosage varies depending on individual needs and the demands of their sport; strength and bodybuilding athletes often use doses 10 to 100 times higher than therapeutic levels (Barceloux and Palmer, 2013). The choice of AAS is based on the substance's anabolic-androgenic ratio and the user's goals, such as increasing body mass during off-season periods (bulking cycles) or reducing body fat while maintaining muscle mass before a competition (cutting cycles) (Fink *et al.*, 2018). Furthermore, a regimen known as "blast and cruise" or "bridging" has become increasingly popular. This involves the continuous use of AAS, alternating between high-dose ("blast") and low-dose ("cruise") periods. Another method, called "blitz" cycling, involves rapid changes in AAS use to prevent tolerance and minimize certain side effects (Sagoe *et al.*, 2015).

The health risks associated with the use and abuse of AAS are diverse; some effects disappear upon discontinuation, while others can be irreversible and life-threatening. These adverse effects affect various body systems, such as the cardiovascular, reproductive, endocrine, hepatic, renal, musculoskeletal, and dermatological systems, in addition to causing neuropsychiatric and behavioral disorders. While most of the scientific literature lacks randomized trials on the long-term effects of AAS abuse due to ethical reasons, case reports and studies of people self-administering AAS provide evidence linking their use to these harmful effects (Goldman and Basaria, 2018; Albano *et al.*, 2021). Furthermore, there is growing concern about the additional health risks posed by the use of black market AAS beyond the already known side effects, representing a significant public health challenge globally (Piatkowski *et al.*, 2025).

Counterfeit anabolic androgenic steroids

The AAS market is characterized by being decentralized and dynamic, with networks of suppliers operating illegally both online and offline, such as in gyms and among bodybuilding communities. The online AAS trade encompasses thousands

of active supplier websites, unregulated companies, and established online forums that serve as sources of information (Brennan *et al.*, 2018). Black market AAS products are often low-quality, counterfeit, and fail to meet pharmaceutical-grade standards. These products may be intentionally designed to mimic legitimate products, but they may lack active ingredients, contain incorrect or harmful substances, or have inaccurate dosages. The widespread availability of low-cost AAS with high concentrations of active ingredients has led to an increase in their use, not only among competitive bodybuilding enthusiasts but also among those seeking purely aesthetic benefits (Fabresse *et al.*, 2021).

Black market AAS can be divided into four main categories: 1) counterfeit versions of products from well-known pharmaceutical companies; 2) items produced by clandestine laboratories; 3) pharmaceuticals from countries where AAS can be purchased without a prescription; and 4) locally manufactured pharmaceuticals obtained through illegal channels. Among these, the most popular are products from clandestine laboratories, marketed under various brand names to create an illusion of legitimacy. These products often claim to meet the highest quality standards, and some even display purportedly modern facilities on their websites or use counterfeit-prevention features, such as holographic seals, to assure buyers of their authenticity. However, these products often contain inconsistent concentrations of active ingredients, cheaper substitutes, or even inactive compounds, compromising their safety and efficacy. Since no official authority regulates these products, their quality control cannot be guaranteed, and manufacturing facilities often fall below the standards required for the production of pharmaceuticals for human use. This lack of regulation creates a high risk of contamination, especially in the case of injectable products (Fink *et al.*, 2019).

Additionally, "homebrew chemistry" is the homemade creation of injectable AAS using raw synthetic androgen powders. This practice has been fueled by the internet, which provides access to raw materials, detailed instructions, and user reports on the homemade production of products containing active pharmacological substances. Online platforms, including cryptocurrency marketplaces, have further facilitated access to synthetic androgen powders. However, the use of these homemade products, or those derived from this process, poses significant risks, often exceeding those associated with other black market products (Brennan *et al.*, 2018).

Several studies have used qualitative and quantitative chemical analysis with chromatographic techniques to examine the chemical composition of the active ingredients of various anabolic agents available on the black market. The initial findings available in the scientific literature were published in the late 1990s and 2000s on products available on the German market, revealing that between 35% and 40% of AAS were counterfeit (Musshoff *et al.*, 1997; Ritsch and Musshoff, 2000; Thevis *et al.*, 2008). Table 1 provides a brief summary of some studies from various countries related to

Table 1. Related studies on the counterfeiting of AAS and other drugs used in enhanced bodybuilding

Reference	Analyzed products	Main findings
Pellegrini <i>et al.</i> , 2012	15 different AAS samples (4 tablet preparations, 7 oil solutions and 4 suspensions for intramuscular injections) seized from the black market in Italy.	Variations in the content of every product studied. With the exception of one product, all had concentrations lower than those indicated. - 8 substituted products - 1 overconcentrated - 2 inert products
Coopman and Cordonnier, 2012	76 products (43 intramuscular AAS and 33 oral preparations including AAS, thyroid hormones, aromatase inhibitors, ephedrine, clenbuterol finasteride and sildenafil) confiscated from the bodybuilders' black market in Belgium.	A third of all products don't match the label (specifically, for injectable AAS up to 50%). - 7 adulterated products - 20 substituted products - 1 inert product Additional compounds present in the different products were underconcentrated.
da Justa Neves <i>et al.</i> , 2013	Forensic reports data obtained from the National Institute of Criminalistics of the Brazilian Federal Police Department on 3,537 AAS, 99 clenbuterol products, 38 growth hormone products and 2 gonadotropin products. These products were seized mainly from smuggling or in raids on places where they were being stored to be sold.	Almost one-third of the products investigated were considered to be counterfeit (31.7%). - 567 (48.6%) did not contain any active ingredient - 330 (28.3%) contained drugs that were different from those stated on the label - 66 (5.7%) did not contain all the drugs stated on the labels - 16 (1.4%) contained additional drugs from those declared
Krug <i>et al.</i> , 2014	337 black market products (including AAS, stimulants, diuretics, peptide hormones, growth factors, and hormone and metabolic modulators) were analyzed. The samples were either obtained from different investigative authorities or directly purchased on the black market via the Internet in Germany.	Only 43% of the black-market products contained the substances declared on respective container labels.
Cho <i>et al.</i> , 2015	19 products including AAS and sport supplements (16 injectables and 3 oral preparations) purchased from the Korean black market.	Approximately 50% of the products were adulterated, some of them contained more than two additional AAS compounds.
Hullstein <i>et al.</i> , 2015	296 products (67% AAS, 28% peptide and protein hormones; the rest were other drugs including clenbuterol, stimulants, antiestrogens, glucocorticoids and cannabinoids) confiscated from the black market in Norway.	Up to 18% of all products were inert products, and specifically for the peptide or protein hormones 20% of the preparations did not contain any prohibited substance.
Kozlik and Tircova, 2016	6 products which are a mixture of 4 testosterone esters obtained from a dealer in Slovakia and online stores.	No presence of one ester in one product and overdose of two esters in other product.
Weber <i>et al.</i> , 2017	1,190 products (889 classified as anabolic agents, 146 to peptide hormones, growth factor-related substances and mimetics, 113 hormone and metabolic modulators, and 42 were either mixtures of compounds or of unknown classification) seized in Swiss.	For the majority of the investigated products, the pharmaceutical quality was unsatisfactory and less than 20% of the products contained the claimed substance in the respective amount. Only 47% of all products were accurately labeled, of which: - 41% for anabolic agents - 66% for peptide hormones, growth-factor-related substances, and mimetics. - 88% for hormone and metabolic modulators
da Justa Neves and Caldas, 2017	328 samples of AAS (87 tablets, 83 aqueous injectable suspensions and 158 oil injectable solutions) and 17 products offered as sports supplements (that contained prohormones and designer steroids) sent to the Brazilian Federal Police for forensic analysis.	The global counterfeiting rate detected for AAS was 42.1% (138 of 328 samples), 28.7% for tablets, 12.0% for suspensions and 65.2% for oily solutions, detecting different types of counterfeit products. Among the counterfeit products, 21 declared to be manufactured by inexistent companies (none of them contained any declared substance).
Riberiro <i>et al.</i> , 2018	16 samples of AAS (10 injectable products, 4 tablets and 2 capsules) provided by the Brazilian Federal Police.	40% of the injectable products did not contain the indicated active ingredient on the packing.
Shapira <i>et al.</i> , 2018	118 samples of AAS from Israel.	44 of 113 (38.9%) had labels misrepresenting actual contents, of which, 20 products (45.5%) had a different active ingredient.

Reference	Analyzed products	Main findings
Tircova <i>et al.</i> , 2019	358 AAS products (243 oil formulations and 115 tablets/capsules) obtained from users in Czech Republic and Slovakia.	Over 40% of the AAS analyzed failed to meet label claims. - 4.5% substituted products - 15.9% inert products - 16.8% under-concentrated products - 3.6% over-concentrated products
Campos <i>et al.</i> , 2020	31 samples of stanozolol (29 tablet and 2 capsule packs) seized by the Brazilian Federal Revenue Service Agency.	90.3% of the samples were adulterated products and 65% exhibited higher concentrations.
Fabresse <i>et al.</i> , 2021	75 products (included 39 oily and 3 aqueous solutions for intramuscular injection, 30 tablets or capsules and 3 lyophilizates) seized from the black market among bodybuilders in France.	Only 19% were original products (formulation and levels of active ingredients fully matches the declared formulation) 33% were substandard (dosage not on the acceptable range defined for original products), and 32% were counterfeit (formulation does not match the label).
Lemos <i>et al.</i> , 2021	30 tablet samples of different AAS seized by the Brazilian Federal Police.	13.3% of the products don't contain any active ingredient. In addition, 6.6% were adulterated products and another 6.6% were inert products.
Odoardi <i>et al.</i> , 2021	409 black market-products (drugs of different classes, including AAS, stimulants, sexual enhancers, and hormone modulators) confiscated from post offices or at storage warehouses of couriers for drugs coming from internet purchase orders; at home or storage facilities of suspect dealers; in clandestine laboratories; and in gyms from Italy.	15% of the products had a composition completely different from that declared, while 10% of products showed cross-contamination with other drugs, mainly testosterone esters, probably due to the presence of residues of other drugs in the production line. In addition, 11% of products were not labeled, so their purported composition was unknown.

Note: Adulterated product: one or more additional prohibited substances detected; Inert product: active ingredient not detected or no active ingredient other than excipient found; Substituted product: the indicated active ingredient is replaced by another substance; Sub-standard products = Under-concentrated products: concentration of the active ingredients is lower than declared; Over-concentrated: concentration of the active ingredients is higher than declared.

counterfeit AAS in different products. To date, counterfeiting of AAS is prevalent internationally, as highlighted by one of the latest reports from the Swiss market, where a study reported that 52% of the analyzed samples were counterfeit products (Magnolini *et al.*, 2025).

Interestingly, analytical results consistently show various qualitative and quantitative discrepancies. In some cases, the declared active compound may be replaced by a similar, lower-cost one or may not even be present; there are also discrepancies between the declared amount and the actual amount present in the product. Furthermore, analyses of multiple samples, including products from the same batch or manufacturer, show results with varying amounts of active compounds. These findings could be due to poor manufacturing quality and a lack of decontamination of production lines, so product sterility is not guaranteed (Odoardi *et al.*, 2021). Some products with AAS have been substituted for steroids of the same class, such as testosterone isocaproate, by other testosterone esters, such as testosterone enanthate or propionate. In some cases, completely different drugs, such as anastrozole, an aromatase enzyme inhibitor, have been used instead of mesterolone, both of which are banned by WADA (Magnolini *et al.*, 2022).

Similarly, some counterfeit oral products include active ingredients originally intended for intramuscular administration (Lemos *et al.*, 2021). Furthermore, certain injectable AAS have been found to contain 17- α -alkylated steroids

(substances formulated for oral use), such as stanozolol and methandrostenolone. This substitution could be intended to mitigate adverse effects such as hepatotoxicity, although it requires more frequent injections rather than daily oral administration. Furthermore, these injectable products may replace the oily excipient with an aqueous solution, sometimes mixed with analgesics to reduce pain during administration (Fabresse *et al.*, 2021).

It is essential to conduct chemical analyses of suspicious and illegal products to verify their composition. It is equally important to increase awareness of the risks associated not only with AAS, but also with other performance-enhancing drugs obtained from the black market (Deconinck *et al.*, 2021).

Counterfeit products pose significant risks due to uncertainty about the types and quantities of AAS they contain. Different AAS have varying anabolic-androgenic properties, leading to a variety of potential adverse effects. Furthermore, since these products are manufactured in clandestine laboratories, they may contain harmful chemical or biological contaminants, further increasing the dangers (Weber *et al.*, 2017).

Counterfeit AAS products pose a threat to public health due to several factors (Odoardi *et al.*, 2021):

The inherent toxicity of androgen derivatives, some of which have unknown toxicological profiles because they are not clinically approved or are intended exclusively for veterinary use. When used at supraphysiological doses for

performance enhancement or image purposes, they can cause health damage, some of which are irreversible. In cases where androgenic steroid mixtures are used, lower doses or the absence of certain ingredients may lead users to consume larger amounts, assuming the effects are minimal.

Incorrect labeling of counterfeit products prevents users from knowing the actual active ingredients and their quantities.

Poor manufacturing standards, lack of quality control, and good manufacturing practices increase the risk of contamination with toxic chemicals such as heavy metals, cross-contamination with other active pharmaceutical ingredients, and microbial contamination.

Selective androgen receptor modulators

Selective androgen receptor modulators (SARMs) are a new class of chemically modified molecules with potential therapeutic applications. These compounds can selectively target androgen receptors, with the goal of reducing androgenic effects and other side effects, such as hepatotoxicity. SARMs are classified into two groups based on their interaction with the androgen receptor: agonists and antagonists. SARMs with agonist activity are not approved for pharmacotherapy, while SARMs with antagonist activity are approved as nonsteroidal antiandrogen drugs, such as flutamide, nilutamide, bicalutamide, and enzalutamide, which are used in the treatment of prostate cancer (Christiansen *et al.*, 2020). Clinical trials with SARMs with agonist activity have demonstrated potential to stimulate muscle growth, promote bone reconstruction, and improve lean body mass in various groups, although results regarding strength gains and performance in humans have been inconsistent (da Fonseca *et al.*, 2020). Although SARMs are not converted into estrogens by aromatase or into more potent androgens by 5 α -reductase (Bhasin and Jasuja, 2009), adverse effects are similar to those of androgen derivatives, including liver injury and alterations in lipid metabolism (Leciejewska *et al.*, 2024). To date, no regulatory health authority has approved the use of SARMs with agonist activity in humans, and they are similarly banned by WADA (Vasireddi *et al.*, 2025).

SARMs with agonist activity are attractive for enhancing various sports, including bodybuilding. Unfortunately, despite the lack of comprehensive toxicological profiles and reliable sources for purchasing these products, their use is common among adolescents and young adults (Hilkens *et al.*, 2021; Efimenko *et al.*, 2022). The popularity of these products among recreational and elite athletes is driven by aggressive online marketing, which often includes false and unapproved health claims about SARMs. A common misleading claim is that these products are a safe alternative to AAS and do not cause adverse effects; however, the long-term risks and potential side effects have not been fully evaluated (Machek *et al.*, 2020).

Most SARMs sold online are marketed as sports supplements. Some of these products even include labels stating "not for human consumption" or "for research purposes only"

(Gaudio *et al.*, 2024). As part of the black market, counterfeit SARMs have been found in up to 60 % of products on the US market (Van Wagoner *et al.*, 2017) and 70 % on the UK market (Leaney *et al.*, 2021). These counterfeit products may contain missing or added compounds, in varying concentrations, and sometimes include active ingredients that do not belong to the SARM group. Many of these substances lack scientific evidence of their efficacy or safety, such as the PPAR δ agonist GW501516, the growth hormone secretagogue ibutamoren, and the nuclear receptor agonist SR9009, all of which are banned by WADA.

Hormone, metabolic modulators and non-approved substances

In addition to AAS and SARMs, other anabolic agents such as protein hormones, insulin analogs, Growth Hormone (GH), and Insulin-like Growth Factor I (IGF-1) have become more popular both inside and outside professional sports, and are often used at supraphysiological doses to enhance performance and muscle mass (Anderson *et al.*, 2018). Online vendors offering a combination of legal and illegal peptide- or protein-based drugs, many of which are of uncertain quality, primarily drive the black market for these substances. The use of these unpredictable substances presents risks, and some of them have not been clinically approved (Krug *et al.*, 2018).

A popular product on the black market, especially among enhanced and amateur bodybuilders, is Long R3-IGF-1. This compound, developed in the late 1990s along with two other IGF-1 analogs, was initially explored as a potential treatment for GH axis disorders. However, only the ergogenic effects of Long R3-IGF-1 have been well documented in animal models, and no human clinical trials have been conducted, likely because other approved drugs for growth deficiencies were developed. While bodybuilding websites often offer guidelines on its use and advertising, there are no scientific studies available on its serum concentration after intramuscular administration, its clearance in humans, or its overall efficacy (Mongongu *et al.*, 2021).

Recently, there has been growing interest among performance-enhancing drugs users in novel synthetic peptides advertised for the repair of sports-related injuries or competitive tasks, to offset the adverse health effects of AAS use and the negative effects of strenuous training, as well as to improve body composition (Turnock, 2022). Most of these compounds are cryptic peptides (crypteins), which are small bioactive molecules generated through the degradation of functionally active proteins; often with unpredictable activity distinct from the parent protein, either as naturally processed fragments or, alternatively, as a result of artificial proteolytic cleavage (Autelitano *et al.*, 2006).

WADA prohibits the use of peptides with performance-enhancing effects, and one such substance recently added to the 2022 prohibited list is BPC-157, classified as an Unapproved Substance S0 (Tian *et al.*, 2023). This compound is

commonly found in vials of injection powder and nasal sprays (Høj *et al.*, 2021). BPC-157 has been discussed online, with claims of its benefits in gaining a competitive edge and aiding in recovery from sports injuries. However, it is critical to note that there is insufficient clinical research documenting its dosage and health risks. Despite this, it is sold online in injectable vials marked “for research purposes only” and “not for human use” (Cox *et al.*, 2017).

Other small peptides include, but are not limited to, growth hormone-releasing factors (GHRFs) and growth hormone-releasing peptides (GHRPs) or their analogues (Judák *et al.*, 2021), which can evade anti-doping tests because even a slight structural modification renders them undetectable since current analytical strategies in drug testing laboratories rely on the analysis of specific substances (Popławska and Błażewicz, 2019). One of the main advantages of GHRPs and growth hormone-releasing hormones (GH-RH) is the pulsatile release of GH, which produces fewer side effects compared to the constant increase when GH is administered exogenously. However, case reports related to doping and image enhancers have shown that these products are highly counterfeited, primarily the growth hormone secretagogues ipamorelin, GHRP-2, GHRP-6, and the hGH-RH analogs sermorelin and CJC-1295, as well as even the anti-obesity peptide AOD-9604. In peptides containing cysteine, a sulfur-containing amino acid, such as AOD-9604, multiple impurities were confirmed, such as the reduction of the cystine bridge and the formation of aggregates/dimers across these bridges. In some preparations identified as AOD-9604, the total amount of impurities was estimated at 95.5%. In one specific case, a vial purportedly containing the peptide CJC-1295 was found to contain insulin (Janvier *et al.*, 2018).

CONCLUSIONS

This article presents the scientific evidence related to the counterfeiting of certain pharmacological ergogenic aids, a situation currently prevalent at an international level. The clandestine production of anabolic agents poses additional risks to users due to the uncertainty of the product's contents and the probable presence of chemical and biological contaminants. Despite being prohibited by sports governing bodies and the lack of sufficient studies confirming the efficacy, safety, and toxicity of certain substances, various anabolic agents and other substances from the black market are fraudulently offered as pharmaceutical-grade products to enhance physical performance, increase muscle mass, and reduce adverse effects. Further research is essential to detect and evaluate counterfeit products, as well as educational programs to discourage the use of these substances by users at any competitive or recreational level.

CONFLICTS OF INTEREST

The authors report no conflicts of interest and no source of funding.

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