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Counterfeit Anabolic Steroids in Brazil: A Forensic Perspective on Quality and Risks

Lucas Caseri Câmara [a*]

[a] *Department of Specialization in Clinical Anabolism, College of Governance, Engineering, and Education of São Paulo - FGE-SP, Brazil.*

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

The illicit use of anabolic androgenic steroids (AAS) poses a significant global health challenge, particularly due to the widespread availability of counterfeit products in underground markets. This review examines AAS seized in Brazil, a country with a notable prevalence of use, especially among gym and sports center attendees. Thus, the main objective of this brief review is to map studies published on the seizure and chemical analysis of AAS sourced from the underground market in Brazil. A comprehensive analysis of studies revealed high levels of adulteration in seized products, including the absence of declared active pharmaceutical ingredients (APIs), the addition of undeclared substances, and contamination with harmful agents such as toxic chemicals or biological impurities. Many of these products significantly diverged from their labeled composition, leading to risks of therapeutic failure, unexpected side effects, or potentially severe health consequences, such as cardiovascular toxicity or organ damage.

The findings align with international trends, highlighting the urgent need for effective measures to

**Corresponding author: E-mail: lucascc_med@hotmail.com;*

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address this issue. Regulatory agencies and law enforcement must enhance their collaboration to prevent the production and distribution of counterfeit AAS. Additionally, the implementation of advanced forensic methodologies, such as chromatography and spectrometry, is essential for identifying adulterated products and ensuring safer oversight of these substances. Public awareness campaigns are equally critical, aiming to educate consumers on the dangers of counterfeit AAS and discourage their use.

This review underscores the pressing need for multidisciplinary approaches that include rigorous regulation, education, and research into harm-reduction strategies. Protecting public health requires a comprehensive understanding of the risks posed by illicit AAS and concerted efforts to mitigate their impact.

Keywords: Anabolic steroids; testosterone; ergogenic aid; bodybuilding; counterfeit drugs.

1. INTRODUCTION

The abuse of AAS worldwide has gained significant attention due to its increasing prevalence and the potential health consequences for most users (Parkinson & Evans, 2006). In this context, Parkinson and Evans (2006) reported in a survey of 500 users that only 0.8% did not experience any side effects throughout their history of use. Additionally, according to the same authors, only 11.6% of AAS use was based on medical prescriptions, with 70.8% being obtained through internet traffickers and 24.2% from gym acquaintances (Parkinson & Evans, 2006).

AAS sourced from the underground market often exhibit a high rate of adulteration, ranging from 18.8% to 86.6%, as previously documented (Câmara, 2023). These adulterations have been identified both qualitatively—where the product does not contain what is listed on the label (e.g., absence of active components, substitution with a different AAS, addition of another AAS, inclusion of non-AAS substances, contamination with biological microorganisms, or toxic contaminants)—and quantitatively, with cases of under- or overdosing, reaching up to 170% for oral products and 221% for oily formulations (Câmara, 2023).

In Brazil, the prevalence of AAS abuse is also notably high, reaching up to 31.6% in specific settings such as gyms and sports training centers, as reported by Abrahin et al. (2014). Furthermore, in a 5-year study, chemically analyzed AAS seizure from the underground market in Brazil have shown a high adulteration rate up to 38.8% (da Justa Neves et al., 2013).

Consequently, two critical and potentially hazardous factors emerge: the high global prevalence of AAS use, particularly in Brazil, and the significant rate of adulteration in underground-market substances, which together may exponentially increase health risks (Abrahin et al., 2014; da Justa Neves et al., 2013). Thus, the main objective of this brief review is to map studies published on the seizure and chemical analysis of AAS sourced from the underground market in Brazil.

2. METHODOLOGY

For the initial research and article search, we utilized MeSH (Medical Subject Headings) terms combined and related to AAS (testosterone congeners, anabolic agents, performance-enhancing drugs) within the PubMed database, in English, Portuguese, or Spanish, with no publication date limits. The structured search strategy is detailed below.

("Counterfeit Drugs"[Mesh] OR "Drugs, Counterfeit" OR "Counterfeit Drug" OR "Drug, Counterfeit" OR "Counterfeit Medicine" OR "Medicine, Counterfeit" OR "Counterfeit Medicines" OR Medicines, Counterfeit" OR "Falsified Drugs" OR Drugs, Falsified" OR "Fake Drug" OR "Drug, Fake" OR "Falsified Medicine" OR "Medicine, Falsified" OR "Falsified Drug" OR "Drug, Falsified" OR "Fake Drugs" OR "Drugs, Fake" OR "Falsified Medicines" OR "Medicines, Falsified" OR "Black market" OR "underground market") AND ((("Performance-Enhancing Substances"[Mesh]) OR ("Anabolic Agents"[Mesh])) OR ("Testosterone Congeners"[Mesh])).

Additionally, we conducted a manual active search for other studies cited as references in the articles retrieved from the initial search. We also explored other scientific databases, including LILACS (Latin American and Caribbean Health Sciences Literature) (terms: anabolic steroids, counterfeit), SCIELO (Scientific

Electronic Library Online) (terms: anabolic steroids, counterfeit), and ResearchGate. These additional searches specifically aimed to identify studies on the topic conducted exclusively in Brazil.

The scientific references from published studies identified in this process were initially saved as titles and abstracts. Subsequently, they were individually selected based on two mandatory criteria: (1) the study involved the seizure of drugs from the underground market circulating exclusively in Brazil; (2) the study reported results of the chemical analysis of the seized substances. When the title and abstract did not sufficiently address these two criteria, the full text was retrieved and reviewed to determine final inclusion or exclusion.

3. RESULTS

The structured search conducted in PubMed yielded a total of 62 results. Additionally, 2 references were retrieved from SCIELO, 2 from LILACS, and 18 from ResearchGate. From the 84 references initially collected, a thorough and detailed selection process was carried out according to the predefined inclusion criteria. This process resulted in the selection of 9 studies that met the requirements for inclusion in this review. A descriptive detailed summary of each study is provided below to enhance understanding and contextualize their findings.

1 – Ames and Souza (2012):

A retrospective descriptive study of forensic reports prepared by Federal Police forensic experts, conducted by Brazilian researchers, involved collaboration with the Faculty of Pharmacy at PUC-RS (Pontifical Catholic University of Rio Grande do Sul) , the graduate program in chemistry at UFRJ (Federal University of Rio de Janeiro), and the technical-scientific sector of the Federal Police (Superintendency of Rio Grande do Sul). The study aimed to analyze counterfeit drugs seized between 2007 and 2010, and the most seizures were carried out in the states of Paraná, São Paulo, and Santa Catarina, with an observed increase of over 200% in the number of counterfeit drugs submitted for forensic analysis during the study period (42 cases in 2007, 84 in 2008, 132 in 2009, and 113 up to September 2010, totaling 371 reports and 610 drugs confirmed as counterfeit after forensic analysis).

As a result, anabolic-androgenic steroids (AAS) were identified as the second-largest category of counterfeit drugs seized (26%), with an increasing trend over time: 17.1% in 2007, 24.5% in 2008, 32.6% in 2009, and 30.4% in 2010. The most frequently seized AAS were Durateston® (8.9%) and Hemogenin® (5.7%).

The study further demonstrated that between 2007 and 2010, although decreasing, there remained a significant prevalence of smuggled counterfeit products (potentially manufactured abroad and brought across borders). These accounted for 34.6% in 2007, 29.8% in 2008, 24.4% in 2009, and 14.3% in 2010.

The authors concluded that products from the underground market fail to meet the standards of efficacy and quality required by ANVISA (National Health Surveillance Agency). Consequently, these products may not only fail to deliver the expected effects but also pose significant risks to consumer health through adverse or side effects.

2 – Ribeiro et al. (2018):

A study conducted by Brazilian researchers affiliated with the Chemistry Institute of São Paulo State University (UNESP) aimed to evaluate the authenticity of 16 AAS samples from the underground market, seized by the Brazilian Federal Police, using proton nuclear magnetic resonance spectroscopy (^{1}H NMR).

The results revealed that 4 of the 16 samples (25%) contained only the oily vehicle (injectable samples) and lacked any active compounds, thus differing from their labeling (adulterated/falsified). Specifically: a) Samples 11 and 12 - Declared: Testosterone Propionate 100 mg/mL / Analyzed: Absence of active compounds; b) Samples 15 and 16 - Declared: Nandrolone Decanoate 100 mg/mL / Analyzed: Absence of active compounds.

The authors concluded that the methodology employed was appropriate and effective, comparable to other commonly used techniques, allowing for a detailed analysis of potentially adulterated substances, specifically AAS from the underground market.

3 – Berneira et al. (2019):

A study conducted by Brazilian researchers in collaboration with the Technical-Scientific

Department of the Federal Police and the University of Pelotas (Rio Grande do Sul state), at the Center for Chemical, Pharmaceutical, and Food Sciences, Lipidomics and Bioorganic Laboratory, aimed to evaluate various samples seized from the underground market using multiple analytical methodologies, including gas chromatography-mass spectrometry, Fourier-transform infrared spectroscopy, and differential scanning calorimetry.

The results revealed that 20% of the analyzed samples contained only the oily vehicle, lacking the active ingredient declared on the label. Additionally, among the samples that contained the active ingredient, 83.3% did not match the labeled concentration, further highlighting evidence of falsification. List 1 summarizing the quantitative chemical characteristics of the adulterated samples.

The authors concluded that, in addition to visual inspection—which may already provide indications of counterfeit products from the underground market (e.g., absence of the manufacturer's address, concentration data, expiration date, and batch number)—more detailed chemical analyses are essential for confirmation and the detection of other characteristics of counterfeit products.

4 – Berneira et al. (2020a):

A study conducted by Brazilian researchers from the Center for Chemical, Pharmaceutical, and Food Sciences at the Federal University of Pelotas (Rio Grande do Sul state) aimed to provide a didactic approach to forensic education for undergraduate students by analyzing two formulations from the underground market using visual inspection, infrared spectroscopy, gas chromatography, and mass spectrometry.

The results revealed that during visual inspection, the first sample (Testosterone Propionate) displayed differences when compared to the original product, providing clear evidence of counterfeiting. However, no visual discrepancies were detected in the second sample (Nandrolone Decanoate).

Chemical analyses showed that both samples were adulterated and did not match the labeling. The first sample (Testosterone Propionate) contained no active ingredient, consisting only of an oily vehicle. The second sample (Nandrolone Decanoate) contained the declared AAS but was combined with various excipients, including ethyl esters of fatty acids and benzyl benzoate.

The authors concluded that visual inspection alone may be insufficient for distinguishing counterfeit products from the underground market. Sophisticated chemical analytical methods are required for proper forensic evaluation of these frequently adulterated products.

5 – Berneira et al. (2020b):

A study conducted by Brazilian researchers from the Center for Chemical, Pharmaceutical, and Food Sciences at the Federal University of Pelotas (Rio Grande do Sul state) aimed to test and compare different analytical methodologies (chromatographic, spectroscopic, and spectrometric) for evaluating AAS samples from the underground market, seeking potential adulterations and cytotoxicity.

The study analyzed 11 products seized by the Brazilian Federal Police in Pelotas city and provided for laboratory testing. The results indicated that the majority (7 out of 11 samples, corresponding to 63.6%) had compositions differing from those declared on their labels, as detailed in List 2.

Visual inspection revealed evidence that samples 6 to 11 were counterfeit, as their brand names and manufacturers were not licensed for commercialization in Brazil. Additionally, essential information such as manufacturer address, concentration, expiration date, and batch number was missing from some samples, further supporting suspicions of counterfeiting.

List 1. Quantitative chemical characteristics of the adulterated samples

Sample	Labeling concentration	Analysis results
1	Oxymetholone 50 mg/tab	14.4 ± 0.29 mg/tab
4	Stanozolol 50 mg/mL	18.19 ± 1.42 mg/ml
6	Nandrolone Decanoate 200 mg/mL	205.69 ± 15.85 mg/ml
7	Testosterone Propionate 100 mg/mL	Absence of active compound
8	Trenbolone Acetate 100 mg/mL	Absence of active compound

List 2. Labelling of the samples in accordance to their compositions

Sample	Labeling	Analysis results
2	Unknown (no label)	Stanozolol
6	Boldenone Undecylenate	Nandrolone Decanoate
7	Testosterone Blend (esters)	Testosterone and Nandrolone Esters
8	Testosterone Propionate	Testosterone and Nandrolone Esters
9	Stanozolol	Absence of active compound
10	Testosterone Propionate	Absence of active compound
11	Trenbolone Acetate	Absence of active compound

Chemical analyses also revealed that three samples had counterfeit oily vehicles, with substances resembling soybean oil being identified. This is in contrast to more commonly used vegetable oils in pharmaceutical formulations, such as castor oil, peanut oil, sesame oil, and benzyl benzoate.

The authors concluded that, when available, diverse analytical methodologies should be part of the forensic toolkit for evaluating products from the parallel market. These methods complement initial visual inspection, allowing for accurate detection of counterfeits.

6 – Coimbra et al. (2021):

A study conducted by Brazilian researchers affiliated with the Department of Pharmaceutical Sciences at the Health Sciences University of Porto Alegre (Rio Grande do Sul state), the National Institute of Forensic Science and Technology (INCT Forense) in Porto Alegre, and the School of Pharmaceutical Sciences at the University of São Paulo (USP), aimed to evaluate 115 illegal products suspected of counterfeiting. These products were seized by the Brazilian Federal Revenue postal service between 2016 and 2017 in the state of Rio Grande do Sul.

The samples were primarily labeled as AAS (oily, for intramuscular application) and were analyzed using specific mass spectrometry techniques. The study identified the most frequently found AAS as follows: a) 60.8% Testosterone and its esters (n = 70); b) 18.2% Methandienone (n = 21); c) 10.4% Trenbolone Acetate (n = 12).

A notable finding was that all the qualitatively tested samples contained more than one AAS in their composition, except for a single sample that contained only Methandienone. Furthermore, quantitative analyses revealed that all samples had lower concentrations of active compounds compared to legally marketed products for human or veterinary use, despite the labels on the seized products declaring higher concentrations than those detected.

The authors concluded that the employed method was effective and could be used by regulatory agencies to evaluate counterfeit products. They also emphasized that the poor quality of these products increases health risks for users of underground market AAS.

7 – Lemos et al. (2021):

A study conducted by Brazilian researchers from the National Institute of Forensic Science and Technology (INCT Forense) in Porto Alegre, the Federal Police Superintendency of Rio Grande do Sul, the General Forensic Institute (Rio Grande do Sul state), and the Department of Analysis at the Federal University of Rio Grande do Sul aimed to analyze 30 oral tablets labeled as AAS and suspected of irregularities from the underground market using Fourier-transform infrared spectroscopy.

The results indicated that nine samples (30%) labeled as originating from China and India and suspected of irregularities showed adulterations. In some samples, no active ingredient (AAS) was detected, while others contained additional substances, albeit in smaller quantities than the predominant AAS. The adulterated samples identified through the analyses are presented in List 3.

The authors concluded that the methodology employed in the analyses was effective, as were other commonly used methods for this purpose. It represents a potential strategy for forensic assessment of substances from the underground market, which are frequently adulterated.

8 – Berneira et al. (2022):

A study conducted by Brazilian researchers affiliated with the Lipidomics and Bioorganic Laboratory, Forensic Chemistry, the Center for

Food Chemistry and Pharmaceutical Science at the University of Pelotas (Rio Grande do Sul state), and the Forensic Institute of RS (Rio Grande do Sul) aimed to analyze products seized from the underground market by the Brazilian Federal Police.

The methodology involved gas chromatography and mass spectrometry, as well as a cytotoxicity assay using cell cultures to assess the cellular effects of the seized samples. List 4 presents the chemically analyzed adulterated samples, highlighting discrepancies between their labeling and chemical composition.

The researchers noted that, consistent with numerous previously published studies, the quality of products from the parallel market is highly questionable. In this analysis, a 66.7% adulteration rate was observed. Additionally, in the cell culture assay, the analyzed compounds demonstrated cytotoxicity, with a positive correlation to concentration, meaning that higher doses resulted in greater toxicity, and vice versa.

The authors concluded that AAS acquired illegally are often of poor quality and unknown composition (sometimes lacking active ingredients altogether), potentially leading to unknown or severe health risks for users.

9 – de Moura et al. (2023):

A retrospective study conducted by Brazilian researchers from the Department of Chemistry at the Institute of Exact Sciences, Federal University of Minas Gerais, analyzed pharmaceuticals seized by the Civil Police of Minas Gerais between 2017 and 2022, totaling 6,355 samples.

As a result, throughout the study, 265 pharmaceutical presentations of anabolic androgenic steroids (AAS) were evaluated (corresponding to 32,7%), resulting in the identification of 2,071 active pharmaceutical ingredients (APIs). Testosterone and its derivatives were the most prevalent substances, accounting for 47% of the cases, followed by stanozolol (12.5%), trenbolone (10.8%), and nandrolone (9.1%).

Additionally, only 41.9% of the samples contained APIs that matched the information declared on their labels, while 23.4% showed discrepancies in declared APIs, 30% lacked mandatory details such as administration route and technical accountability, and 10.2% included additional APIs not specified on the label. Many products contained multiple APIs, with the most common combinations involving derivatives of the same compound.

The authors note in their conclusions that the use of AAS is linked to significant health risks, including cardiovascular adverse effects and potential dependency. The presence of counterfeit or substandard products exacerbates these risks, further compromising safety and therapeutic efficacy.

List 3. Adulterated samples are identified through analyses

Sample	Labeling	Analysis Results
733	Methandrostenolone	Absence of active compound
739	Oxymetholone	Testosterone Propionate
747	Oxandrolone	Testosterone Propionate
775	4-Chlorodehydromethyltestosterone	Clostebol Acetate
787	Oxymetholone	Oxymetholone and Methandrostenolone
791	Methandrostenolone	Methandrostenolone and Sildenafil Citrate
839	Mesterolone	Absence of active compound
847	Oxandrolone	Absence of active compound
929	Mesterolone	Absence of active compound

List 4. Discrepancies between the labeling of samples and chemical composition

Sample	Labeling	Analysis results
4	Boldenone Undecylenate	Nandrolone Decanoate
5	Testosterone Ester Blend	Testosterone and Nandrolone Esters
6	Testosterone Propionate	Testosterone and Nandrolone Esters
7	Stanozolol	Absence of active compound
8	Testosterone Propionate	Absence of active compound
9	Trenbolone Acetate	Absence of active compound

4. DISCUSSION

The use of anabolic androgenic steroids (AAS) represents a significant public health concern, further aggravated by the widespread availability of products from the illicit market (Parkinson & Evans, 2006; Graham et al., 2009). This issue, which is widely recognized on a global scale (Sagoe et al., 2014), is particularly alarming in Brazil, where the prevalence of AAS use in gyms and sports centers has been reported to reach as high as 31.6%, according to Abrahin et al. (2014). The high prevalence of these substances, combined with the alarming rates of adulteration observed in illicit markets, substantially increases health risks for users and poses considerable challenges for regulatory and public health systems (Parkinson & Evans, 2006; Abrahin et al., 2014; da Justa Neves et al., 2013; Graham et al., 2009; Sagoe et al., 2014).

The findings of this review highlight the critical nature of this issue, with adulteration rates ranging from 20% to 86% in the studies analyzed. These findings, specifically in Brazil, align with observations reported in various other countries, as summarized in our previously published review (Câmara, 2023).

Documented irregularities include the absence of active pharmaceutical ingredients (APIs), substitution with different compounds, the addition of undeclared APIs, and contamination with biological agents or toxic substances (de Moura et al., 2023). Ribeiro et al. (2018) reported that 25% of the samples analyzed consisted solely of oily vehicles without any active ingredients, while Berneira et al. (2020b) found that 63.6% of the analyzed samples had compositions that deviated from their labeling. These findings underscore the consistently poor quality of products obtained from illicit markets.

Adulteration of AAS not only compromises the expected therapeutic efficacy but also exposes users to significant health risks (Ritsch & Musshoff, 2000). Among the commonly reported effects are increased skin oiliness and acne, gynecomastia, mood and behavioral changes, sexual dysfunction and testicular atrophy, water retention, insomnia, injection site pain, skin striae, increased body hair, hair loss, voice deepening, clitoral enlargement, elevated blood pressure, and alterations in cholesterol profile and liver enzymes (Parkinson & Evans, 2006; Goldman & Basaria, 2018).

Products with inaccurate API concentrations can result in overdoses or subtherapeutic effects, increasing the likelihood of severe and irreversible health consequences. Furthermore, the presence of contaminants, such as heavy metals, coupled with unreliable information about the chemical composition of these products, exacerbates the risks for users (Câmara, 2023; Ames & Souza, 2012; de Moura et al., 2023).

The limitations in monitoring and controlling the illicit AAS market were also evident. The lack of reliable data on manufacturers, API concentrations, expiration dates, and batch numbers complicates the tracking and assurance of these products' safety (Câmara, 2023; Ames & Souza, 2012; de Moura et al., 2023). Coimbra et al. (2021) highlighted that many of the analyzed samples lacked basic labeling information, reflecting the illicit nature of their production and distribution. Insufficient enforcement allows such products to remain widely accessible, particularly through online platforms, as noted by Parkinson and Evans (2006).

A limitation of the present study is that, despite the data presented highlighting the questionable quality of drugs from the illicit market, only nine studies were identified, some of which involved a small number of seized or analyzed samples. Therefore, given the high prevalence of use in Brazil, combined with the fact that the majority of drugs are sourced from the illicit market, the accuracy of the findings in reflecting the full scope of the potential issue may be compromised.

The public health impact extends beyond immediate physical risks. The poor quality of these products hampers the establishment of causality in clinical studies, undermining the reliability of case reports and case series (Kimergård et al., 2014; Câmara, 2024). Moreover, the widespread availability of AAS in the illicit market encourages risky behaviors among users, such as indiscriminate use of adulterated or unverified substances (Parkinson & Evans, 2006).

Addressing these challenges requires the implementation of more effective strategies to

combat the distribution of adulterated AAS. This includes enhanced collaboration between regulatory agencies, such as ANVISA, and law enforcement authorities, alongside improvements in the analytical methodologies used for forensic evaluations (Ames & Souza, 2012; de Moura et al., 2023; Graham et al., 2009). Advanced techniques, such as gas chromatography and mass spectrometry, have proven essential for detecting adulterations and should be widely adopted (Coimbra et al., 2021). Additionally, public awareness campaigns are critical to educate consumers about the dangers of these products and to encourage safer practices.

Finally, we think that fostering prospective studies and epidemiological analyses is essential to deepen the understanding of AAS use and its impacts in Brazil. The involvement of multidisciplinary teams, including toxicologists, healthcare professionals, and public policy experts, will be pivotal in addressing this issue comprehensively (Bonnecaze et al., 2021; Bates et al., 2019). The findings of this review emphasize the urgent need for an integrated and robust approach to mitigate the potential negative effects of illicit AAS on public health.

5. CONCLUSIONS

This review highlights the substantial risks associated with the use of anabolic androgenic steroids sourced from underground markets in Brazil. The high prevalence of adulteration, ranging from absent APIs to toxic contaminants, compromises the safety and efficacy of these products, can increase the likelihood of severe health consequences for AAS users. These findings align with global reports, demonstrating that counterfeit AAS is a pervasive issue. Addressing this problem requires enhanced collaboration between regulatory agencies and law enforcement to curb the production and distribution of counterfeit AAS. Moreover, the adoption of advanced forensic analytical techniques and the promotion of educational campaigns are essential to inform the public about the potential dangers of these products. Future research should focus on developing effective harm-reduction strategies and improving surveillance of the illicit AAS market to better protect public health.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The authors declare that generative AI was used only at the final stage of manuscript preparation (after writing) and exclusively for linguistic refinement in English Language (Name: ChatGPT; Version: GPT-4; Model: OpenAI's Large Language Model; Source: OpenAI - https://openai.com). No original text was generated or substantively edited by the AI.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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