

FORENSIC TOXICOLOGY AT THE INTERSECTION OF DRUGS OF ABUSE AND PUBLIC HEALTH

TOXICOLOGIA FORENSE FRENTE A INTERSEÇÃO DROGAS DE ABUSO E SAÚDE PÚBLICA

TOXICOLOGÍA FORENSE EN LA INTERSECCIÓN DE LAS DROGAS DE ABUSO Y LA SALUD PÚBLICA



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Lucas Dornas Xavier¹, Lucas Albanaz Vargas², Davi Nunes da Silva³, Andressa Carvalho de Oliveira⁴

ABSTRACT

Forensic toxicology applies scientific knowledge to identify and analyze toxic substances in legal and public health contexts, and is fundamental to combating drugs of abuse. These include legal substances such as alcohol and tobacco, and illegal substances such as cocaine, derivatives like crack, and new psychoactive substances (legal highs), which have serious consequences for health and society. The objective of this scientific study was to review the contributions and updates of forensic toxicology, highlighting its importance for public health and justice. The methodology involved a literature review in databases such as PubMed and LILACS, considering studies from the last 20 years and focusing on techniques and advances in the field. Forensic toxicology has evolved since the 19th century, with the development of methods such as chromatography and mass spectrometry, which allow for precise analyses in biological matrices such as blood and urine. Techniques such as immunochromatography have demonstrated efficiency in drug screening, while information systems monitor cases of intoxication and underreporting. The analysis of crack cocaine, for example, highlights its devastating impact and the importance of rigorous methods such as thin-layer chromatography. Controlling new drugs requires international collaboration and dynamic legislation. Forensic toxicology is considered essential for monitoring substances, identifying consumption patterns, and informing public policies, being indispensable for addressing the problem of drug abuse and protecting the health and safety of society.

Keywords: Forensic Toxicology. Drug Abuse. Public Health.

RESUMO

A toxicologia forense aplica conhecimentos científicos para identificar e analisar substâncias tóxicas em contextos legais e de saúde pública, sendo fundamental para o enfrentamento às drogas de abuso. Estas incluem substâncias lícitas, como álcool e tabaco, e ilícitas, como

¹ Medical Doctor. Universidade de Brasília. E-mail: dornas2022@gmail.com

² Doctor of Medical Sciences. Universidade de Brasília. E-mail: albanazvargas@gmail.com

³ Graduated in Dentistry. ICESP. E-mail: daviumbra@gmail.com

⁴ Medical Doctor. Universidade de Brasília. E-mail: andressacavalho2099@gmail.com

cocaína, derivados como o crack e novas substâncias psicoativas (legal highs), que têm consequências graves para a saúde e a sociedade. O objetivo deste estudo científico foi revisar as contribuições e atualizações da toxicologia forense, destacando sua importância para a saúde pública e a justiça. A metodologia envolveu uma revisão bibliográfica em bases como PubMed e LILACS, considerando estudos dos últimos 20 anos e focando em técnicas e avanços no campo. A toxicologia forense evoluiu desde o século XIX, com o desenvolvimento de métodos como cromatografia e espectrometria de massa, que permitem análises precisas em matrizes biológicas como sangue e urina. Técnicas como imunocromatografia demonstraram eficiência na triagem de drogas, enquanto sistemas de informação monitoram casos de intoxicação e subnotificação. A análise do crack, por exemplo, destaca seu impacto devastador e a importância de métodos rigorosos como a cromatografia em camada delgada. O controle de novas drogas requer colaboração internacional e legislações dinâmicas. Considera-se que a toxicologia forense é essencial para monitorar substâncias, identificar padrões de consumo e subsidiar políticas públicas, sendo indispensável para enfrentar o problema das drogas de abuso e proteger a saúde e a segurança da sociedade.

Palavras-chave: Toxicologia Forense. Abuso de Drogas. Saúde Pública.

RESUMEN

La toxicología forense aplica el conocimiento científico para identificar y analizar sustancias tóxicas en contextos legales y de salud pública, y es fundamental para combatir las drogas de abuso. Estas incluyen sustancias legales como el alcohol y el tabaco, e ilegales como la cocaína, derivados como el crack y las nuevas sustancias psicoactivas (drogas legales), que tienen graves consecuencias para la salud y la sociedad. El objetivo de este estudio científico fue revisar las contribuciones y actualizaciones de la toxicología forense, destacando su importancia para la salud pública y la justicia. La metodología implicó una revisión bibliográfica en bases de datos como PubMed y LILACS, considerando estudios de los últimos 20 años y centrándose en las técnicas y avances en el campo. La toxicología forense ha evolucionado desde el siglo XIX, con el desarrollo de métodos como la cromatografía y la espectrometría de masas, que permiten análisis precisos en matrices biológicas como la sangre y la orina. Técnicas como la inmunocromatografía han demostrado su eficacia en el cribado de drogas, mientras que los sistemas de información monitorizan los casos de intoxicación y el subregistro. El análisis del crack, por ejemplo, pone de relieve su impacto devastador y la importancia de métodos rigurosos como la cromatografía en capa fina. El control de nuevas drogas requiere colaboración internacional y una legislación dinámica. La toxicología forense se considera esencial para el monitoreo de sustancias, la identificación de patrones de consumo y la fundamentación de políticas públicas, siendo indispensable para abordar el problema del abuso de drogas y proteger la salud y la seguridad de la sociedad.

Palabras clave: Toxicología Forense. Abuso de Drogas. Salud Pública.

1 INTRODUCTION

Forensic toxicology is defined as the application of toxicology for the purposes of the law, in turn, toxicology, itself, is the study of toxicants. These definitions are, in fact, quite broad, and the most common application of forensic toxicology is the identification of substances that could be involved in deaths or damage to the health of individuals or be the cause of damage to property and the environment. There are reports of the use of drugs by man since very ancient times, but until the Renaissance it was very difficult, perhaps impossible, to prove poisoning by scientific evidence. It was only in the nineteenth century that forensic toxicology emerged as a science and contributed to justice in these cases (Dorta, 2018).

However, there are reports of toxicological knowledge applied to the legal environment since ancient Greece and ancient Rome, bringing some contribution to poisoning crimes, which became commonplace at that time. Thus, scientific knowledge in chemistry, physics and biology was used as a decisive tool in the investigation of issues related to the judiciary and the evolution of this knowledge promoted union, with the development of methods and techniques that reach reliable results in their analyses. Contrary to the imaginary formed, the routine of the forensic toxicologist is not limited to laboratories, often, the forensic work begins or even takes place in external locations, where the conditions found are totally different from a controlled environment (Lopes, 2022).

Regarding the drugs of abuse, these are psychoactive substances from various natural or synthetic compounds that act on the nervous system, generating changes in the functions that regulate thoughts, emotions and behavior. There is legislation for the control and inspection of these toxics, whether for recreational use such as alcohol or tobacco; for pharmacological use, such as opioids or other analgesics; or for general use, such as industrial solvents. There is also the group of illicit drugs, restricted only to medical or research purposes, as is the case of cocaine and its derivatives. These substances lead to various organic consequences to organs and systems of the human body, either in the short term with intoxication or in the long term with chronic organic lesions, in addition to predisposing to risky sexual behaviors and dependence. Addiction disorder is characterized as an intense need for the substance and loss of the ability to control its consumption, in addition to adverse consequences on health status or interpersonal, family, academic, professional, or legal functioning (PAHO, 2022). Between 2010 and 2020, there was a global increase in the consumption of drugs of abuse, becoming a serious public health problem, with an increase in the consequences already mentioned, such as intoxication and dependence, and Brazil was no different from this pattern (Soares, 2021).

In this context, forensic toxicology plays a crucial role in the fight against drugs of abuse, being an area of science that applies chemical and biological principles to identify toxic substances and their effects on the human body, often in legal or criminal contexts. With regard to drugs of abuse, it is essential to detect and quantify these substances in biological samples, such as blood, urine, hair and tissues, helping to clarify cases of intoxication, overdose, accidents or even suspicious deaths. The confrontation permeates the legal field, having direct impacts on public health through accurate analyses, it provides essential data for monitoring the use of illicit drugs, assisting in the elaboration of public policies aimed at preventing and combating them. Based on this holistic view, the importance of the intersection between forensic toxicology, drugs of abuse, and public health is understood. Therefore, the objective of this scientific manuscript is to study and review the role, contributions and updates of forensic toxicology in the face of drugs of abuse and public health. The justification for the elaboration of this bibliographic review is based on the fact that this theme is a modern and relevant agenda in Brazil and in the world, as well as an object of study in different sectors of society and sciences, with gaps yet to be filled, as this study proposes to do.

2 DEVELOPMENT

2.1 FORENSIC TOXICOLOGY

Toxicology is the science that has the function of identifying and quantifying the adverse effects related to exposure to certain agents, called toxicants, which can be organic or inorganic chemical substances. Since ancient times, the elucidation of deaths associated with chemical substances was a concern, however, the toxicologist Mateu Josep Bonaventura Orfila i Rotger (1787-1853), was the first to relate autopsy material with chemical analysis, bringing to light cases of poisoning that had a legal nature, adopting new methods of forensic analysis. From this perspective, forensic toxicology aims to detect and quantify toxic substances, until the twentieth century, it was restricted to identifying the toxic origin of a certain crime, currently this science acts both on the corpse to detect overdose, anaphylactic reaction to drugs, and on the living individual, to trace drugs of abuse and characterize a state of drug dependence (Castelari, 2018; Dorta, 2018).

In this context, forensic toxicological analyses stand out, which are the investigation of compounds of forensic interest, with special emphasis on drugs of abuse, in various biological matrices such as blood, urine, hair, oral fluid, sweat, vitreous humor and meconium. The particular characteristics of each matrix determine which preparation techniques are required, with their advantages and limitations. For example, the techniques that stand out are: protein precipitation, liquid-liquid extraction, solid-phase extraction, extraction with disposable tips,

solid-phase microextraction, and *headspace extraction*. Each method is evaluated for efficiency, cost, sensitivity, selectivity, and environmental impact (Bordin, 2015).

Forensic toxicology has an interdisciplinary role in criminal investigations and judicial proceedings, highlighting its importance in the identification, detection and quantification of chemical substances or toxic elements present in biological matrices *ante mortem* or *post mortem*. The complexity of this area is highlighted, given the diversity of substances, the particularities of the biological matrices used and the chemical phenomena that can influence the results, such as *post-mortem* redistribution, in addition, the importance of rigorous procedures from collection to analysis is reinforced to ensure the reliability of the evidence, including conservation, identification in order to reach a chain of custody of the samples (Oliveira, 2023).

2.2 DRUGS OF ABUSE

Drugs of abuse refers to any licit substance, with an emphasis on alcohol and tobacco, or illicit substance associated with dependence, which corresponds to a pattern of use that corresponds to a pattern of use that leads to suffering of any kind, possibly associated with withdrawal or other symptoms. Alcohol and tobacco are the most widespread and socially accepted substances of abuse, one of the reasons is their legal nature, however they are considered initiation drugs and one of their negative effects is to increase the risk of illicit drug use. The use of drugs of abuse has been socially accepted for thousands of years, however, since the twentieth century, unrestricted use has become a global public health problem. Illicit drugs are also prevalent in the world's adult population, another important issue, it is estimated that about 5% of the world's adult population used some illicit drug in 2015. There is also the emergence of new drugs of abuse, an expanding market, with greater powers, which is accompanied by greater side effects such as intoxication and even fatal events (Soares, 2021).

The Pan American Health Organization (PAHO) warns about substance abuse, highlights that the use of psychoactive substances, such as alcohol, tobacco, illicit drugs and medications, can cause dependence, physical and mental health problems, as well as significant social impacts. Evidence-based interventions are key to preventing use, treating addiction, and minimizing harm. PAHO promotes integrated approaches and public policies to reduce the public health impact of substance abuse (PAHO, 2022).

Drugs of abuse are chemical substances that are harmful to health, representing a modern public health problem, despite being present in history practically since its beginnings. Therefore, they are controlled worldwide. Despite its historical and cultural use,

consumption worries authorities, especially in Europe and among young people, due to the impact on public health. The rapid emergence of new substances challenges forensic toxicology laboratories, which analyze drugs such as opiates, cocaine, amphetamines, and cannabinoids, preferably in blood (Silva, 2020).

2.3 FORENSIC TOXICOLOGY AS A TOOL TO COMBAT DRUGS OF ABUSE

Forensic toxicology is a fundamental science in the fight against drugs of abuse, as it allows detecting, identifying, and quantifying chemical substances in biological matrices such as blood, urine, and tissues. This area is essential for criminal investigation, but also for public health issues, collaborating with the creation of public policies and knowledge relationships (Silva, 2020).

Studies explore the use of enzyme immunoassays in the detection of psychoactive substances in biological matrices in the forensic context. The technique, widely used for urine, faces challenges when adapted to whole blood, due to the complexity of the matrix. The study investigated the efficacy of liquid-liquid extraction and subsequent analysis in the EMIT® system for different xenobiotics, including cocaine, benzodiazepines, amphetamines, barbiturates, opioids, and cannabinoids. The results indicated the feasibility of the method for most substances, except for cannabinoids, where there were limitations in detection. The affordable cost and the precision achieved (coefficient of variation less than 11%) show the potential of the technique for small and medium-sized laboratories, having the potential to benefit on a public scale (Fukushima, 2009).

Another technique explored was the use of immunochromatography, used as a screening technique for the analysis of drugs of abuse in the context of forensic chemistry. In a Brazilian study, the technique was applied to samples of marijuana, cocaine, and ecstasy pills seized by the Civil Police of Minas Gerais (Pinto, 2015). Results showed high sensitivity (94%) and specificity (75%) for cocaine and marijuana, while ecstasy pills showed a high rate of false positives due to the presence of analogous substances. Thus, immunochromatography proved to be efficient, especially for cocaine, as a complementary alternative to colorimetric tests (Borges, 2013; Pinto, 2015).

Studies highlight the role of forensic toxicological analysis in the detection of drugs of abuse, highlighting the use of chemical techniques as a fundamental tool for justice and public health. Methods such as chromatography and mass spectrometry are presented, widely used in laboratories to identify and quantify chemical substances in biological and non-biological samples. The application of these contributes to criminal investigations, control of illicit substances, and combating trafficking (Mori, 2021). Forensic chemistry as an essential tool

for this function of detecting and combating drugs of abuse is also the subject of another study that exalts the methods of high-performance liquid chromatography and gas chromatography coupled to mass spectrometry, allowing the quantification of drugs such as alcohol, marijuana and cocaine of different biological matrices (Gomes, 2013; Sousa, 2016).

The technique of tandem mass spectrometry coupled to liquid chromatography was explored by a study that sought to identify, as well as quantify drugs of abuse in the urinary biological matrix. The highlight of this technique is its sensitivity and selectivity, allowing the detection of small amounts of drugs in complex matrices. The method can simultaneously identify and quantify 53 types of drugs of abuse, including new compounds, with high accuracy and efficiency. This makes it a valuable tool for areas such as clinical toxicology, forensic toxicology, and occupational testing, allowing for large-scale screening and analysis, with optimized workflow, enabling fast and reliable results (McHale, 2024).

2.4 INTERSECTION BETWEEN FORENSIC TOXICOLOGY, DRUGS OF ABUSE AND PUBLIC HEALTH

Forensic toxicology contributes to the identification of toxicants and their effects on organisms, highlighting their essential role in the legal environment through the elucidation of crimes and in the protection of public health. Forensic toxicology works in cases of poisoning, drug overdose, and other infractions, using scientific techniques for the analysis of biological materials, such as blood, urine, and hair. The science is presented as multidisciplinary, covering areas such as occupational, environmental and social toxicology. Rigorous technical analysis allows for the collection of reliable evidence, which is essential for expertise and support for judicial decisions, being a foundation for public health (Jesus, 2021).

A study entitled "Legal *highs*: a public health problem" focuses on the growth and challenges posed by new psychoactive substances, known as "*legal highs*". These substances are created or chemically modified to circumvent existing legislation, often being marketed as legal alternatives to illicit drugs. Despite this, they present significant risks to public health due to the lack of pharmacological and toxicological studies with a high degree of scientific evidence. The rapid introduction of these substances on the market, facilitated by the internet, makes regulatory control difficult and overwhelms forensic laboratories and health systems. In view of this, the article raises the issue of the need for dynamic and comprehensive legislation, including strategies such as temporary prohibitions and the use of generic clauses that cover entire classes of chemical substances, in addition to the importance of national and international partnerships in order to strengthen the fight against this global problem, with serious repercussions at the level of public health (Honorio, 2014).

One thesis presented the development of an information system in the State of Rio de Janeiro, aimed at the epidemiological analysis of poisoning and chemical exposures, as well as the identification of cases of underreporting, with a view focused on public health. The study comprised 6,370 cases between 2000 and 2004, of which 36.96% were considered positive. The most detected substances were alcohol (66.94%), carbamates (12.85%), caffeine (5.33%), anticonvulsants (3.64%) and analgesics (3.30%). Regarding alcohol, it predominated in age groups over 20 years old and in specific municipalities such as Maricá and Teresópolis, while carbamates and medicines showed varied patterns. The research highlighted significant rates of underreporting, especially in the case of drugs of abuse (up to 100%) (Alves, 2005).

A drug of abuse of paramount importance in public health in Brazil is crack, a study addressed the impacts of crack on health and society, with emphasis on the role of forensic toxicology in the identification and analysis of such drug. Crack, derived from cocaine, is consumed through smoke inhalation, which provides intense and rapid effects, but of short duration, stimulating dependence. This drug causes severe damage to the central nervous system and the body as a whole, in addition to exacerbating social problems. At the Botucatu Institute of Criminalistics, preliminary tests, such as the Modified Scott Test, and definitive methods, such as thin layer chromatography, are used to identify crack. In addition, the scientific work reinforces the importance of appropriate therapeutic approaches in the treatment of addiction as a way to mitigate the social impacts of crack (Caccia, 2023).

3 METHODOLOGY

It is a literature review according to a protocol previously written at the beginning of the review, leading to a bibliographic search, carried out in a systematic way of the existing literature on the subject of research.

To prepare the research question, the mnemonic PCC (P - population/participants, C - concept and C - context) was used: "Contributions and updates of forensic toxicology in the face of drugs of abuse and public health?".

Regarding the eligibility criteria, he was guided by the mnemonic itself. The study population was individuals who used drugs of abuse, and the study was *before or after mortem*, for medical or forensic purposes. The concept was based on studying drugs of abuse from the perspective of forensic toxicology, seeking to understand the role of this science in this public health problem, as well as its recent contributions, since chemical substances are often related to public health problems such as this, but in other contexts such as traffic accidents, sexual abuse, among others. The context was limited to studies published in the

last 20 years, which contemplate research on drugs of abuse, relating them to forensic toxicology and public health, providing a panoramic view of this important issue.

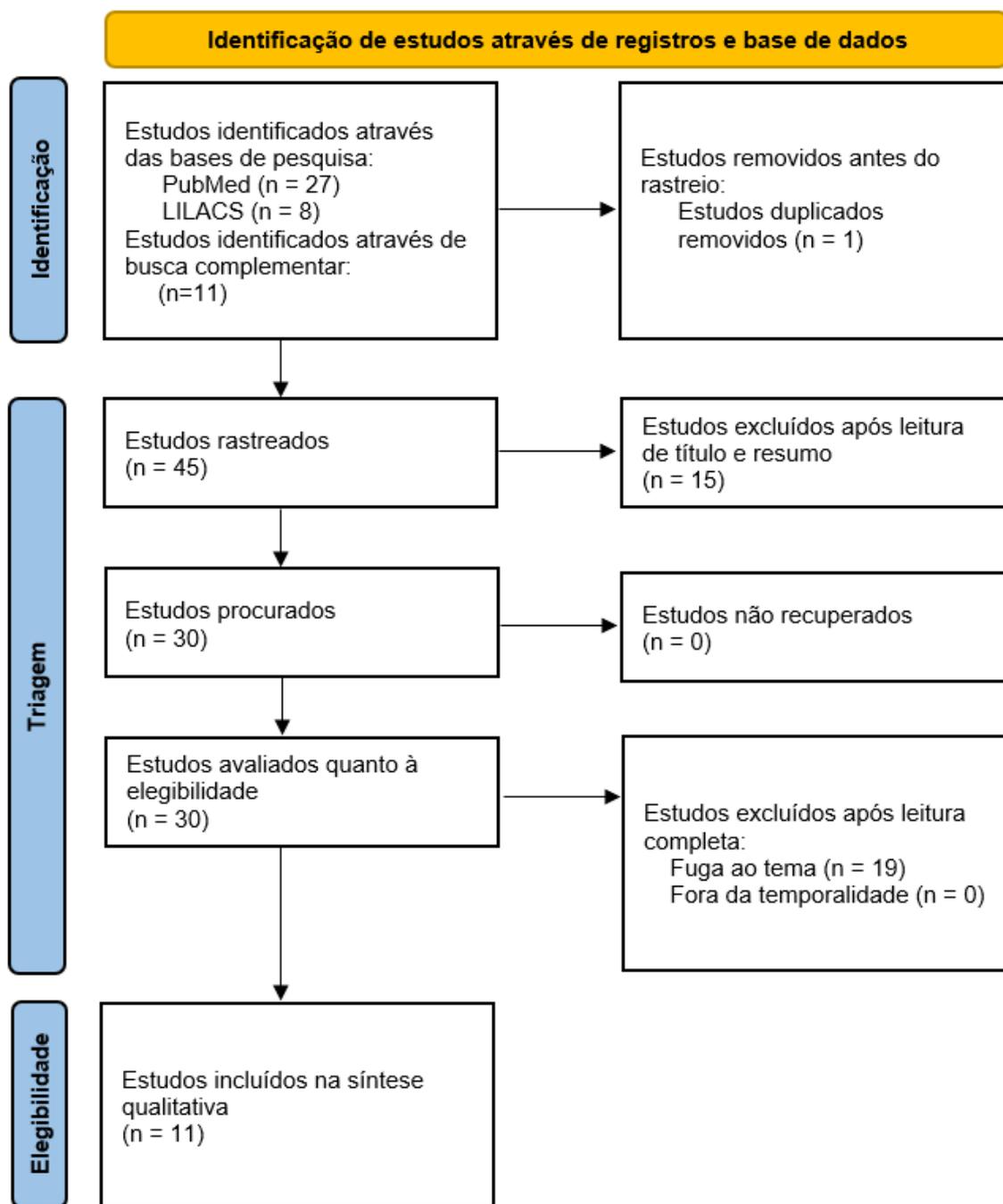
This literature review considered primary studies (original research) and secondary studies (systematic and non-systematic reviews) published or unpublished in national and international portals, repositories, and databases. Duplicates, non-full-text studies, and abstracts published in event proceedings were not considered.

The search strategy began with the identification of controlled descriptors (Mesh and DeCs) and non-controlled descriptors, designed from the keywords of the search question, used for the construction of the initial search strategy, combined or not, such as "Drugs of abuse", "Abuse drug", "Drug of abuse", "Forensic toxicology", "Forensic toxicology", "Public health", "Public health", among others. Through practical experience, the syntax was refined and the search strategies adapted to each database or data repository used. In the PubMed database, based on syntaxes and filters, a number (n) of 23 was found. In the LILACS database, based on syntaxes and filters, the number of 8 articles was found in the chosen time delimitation. In addition to the search in formal databases, a complementary investigation was carried out, including search syntaxes in journals, scientific journals and Google Scholar, in order to enrich and allow a more holistic and comprehensive analysis of the theme. Preprint databases were not searched.

The selection and screening stage of the studies took place in November 2024 and, after the searches, all the identified records were grouped. The first stage consisted of the removal of duplicates; then the title and abstract reading stage. Ultimately, the analysis of the text and references of the selected articles. The titles and abstracts, as well as the studies from the reference lists, were selected by an independent researcher, who evaluated the studies according to the eligibility criteria and the exclusion criteria.

Figure 1

Adapted PRISMA 2020 study flowchart



Source: Authors.

4 FINAL CONSIDERATIONS

Forensic toxicology is an interdisciplinary science that plays a crucial role in tackling drugs of abuse, one of the most complex public health problems. Its ability to monitor substances, identify patterns of use, and track new drugs strengthens the response to this public health problem.

Immunochromatography stands out as a promising tool for preliminary analyses of drugs of abuse, offering practicality and reliability, especially for cocaine and marijuana.

Despite limitations for certain substances, the method complements other forensic techniques, contributing to the elucidation of crimes and drug control.

The application of chemistry in forensic toxicological analysis is fundamental to deal with drug abuse. Methods such as chromatography and spectrometry ensure accuracy and reliability, strengthening both the legal system and public health policies by addressing the social and safety impacts of psychoactive substance use.

From this perspective, these and other analyses allow not only the proof of drug use, but also provide data on consumption patterns, substance metabolism and the correlation with possible harm or deaths related to the use of narcotics. This is essential for criminal investigations, especially in cases of traffic accidents, homicides, abuse of crime-facilitating substances (such as benzodiazepines), and overdoses.

In addition, forensic toxicology assists authorities in controlling new psychoactive substances, whose rapid evolution in the illicit market represents a constant challenge. The fight against new psychoactive substances, such as *Legal Highs*, requires more dynamic legislative strategies and national and international cooperation. Rapid notification systems and partnerships between laboratories and authorities are crucial to keep up with the rapid evolution of these drugs, protecting society from their harmful impacts.

Crack use poses a significant public health and safety challenge. Forensic toxicology plays a central role in identifying the drug and guiding public policy. Adequate treatment for addicts emerges as a vital strategy to mitigate social and economic damage, alongside integrated approaches between health, justice and social programs

The development of toxicological information systems improves the surveillance and monitoring of chemical substances, allowing for more effective tackling of problems such as underreporting. Tools like this guide public policies and strengthen integration between institutions to protect the health and safety of the population.

Therefore, forensic toxicology not only contributes to criminal justice, but also contributes to protecting the health and safety of society, being an indispensable tool in the fight against drugs of abuse as a public health problem.

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