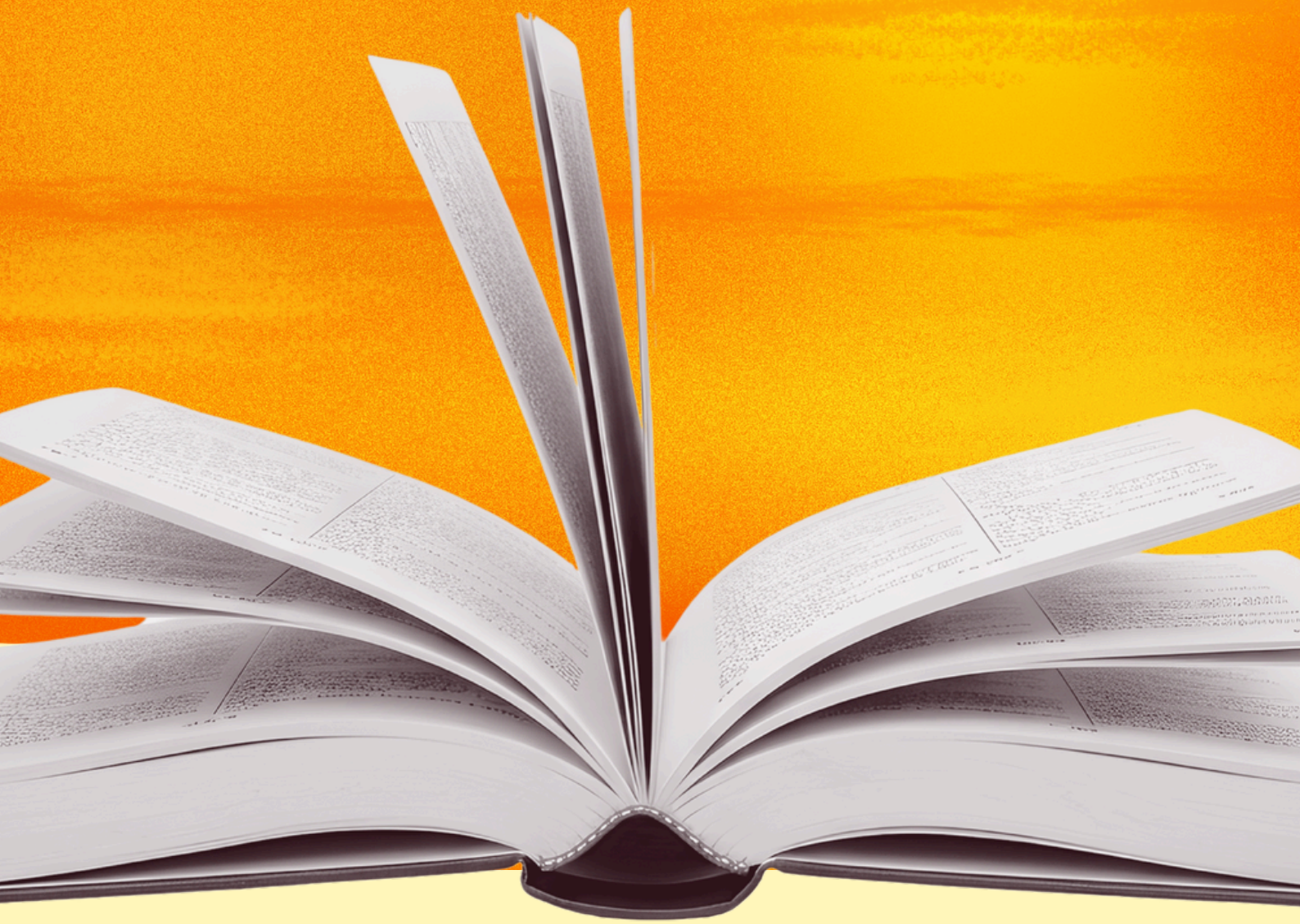
Aurum
EDITORA

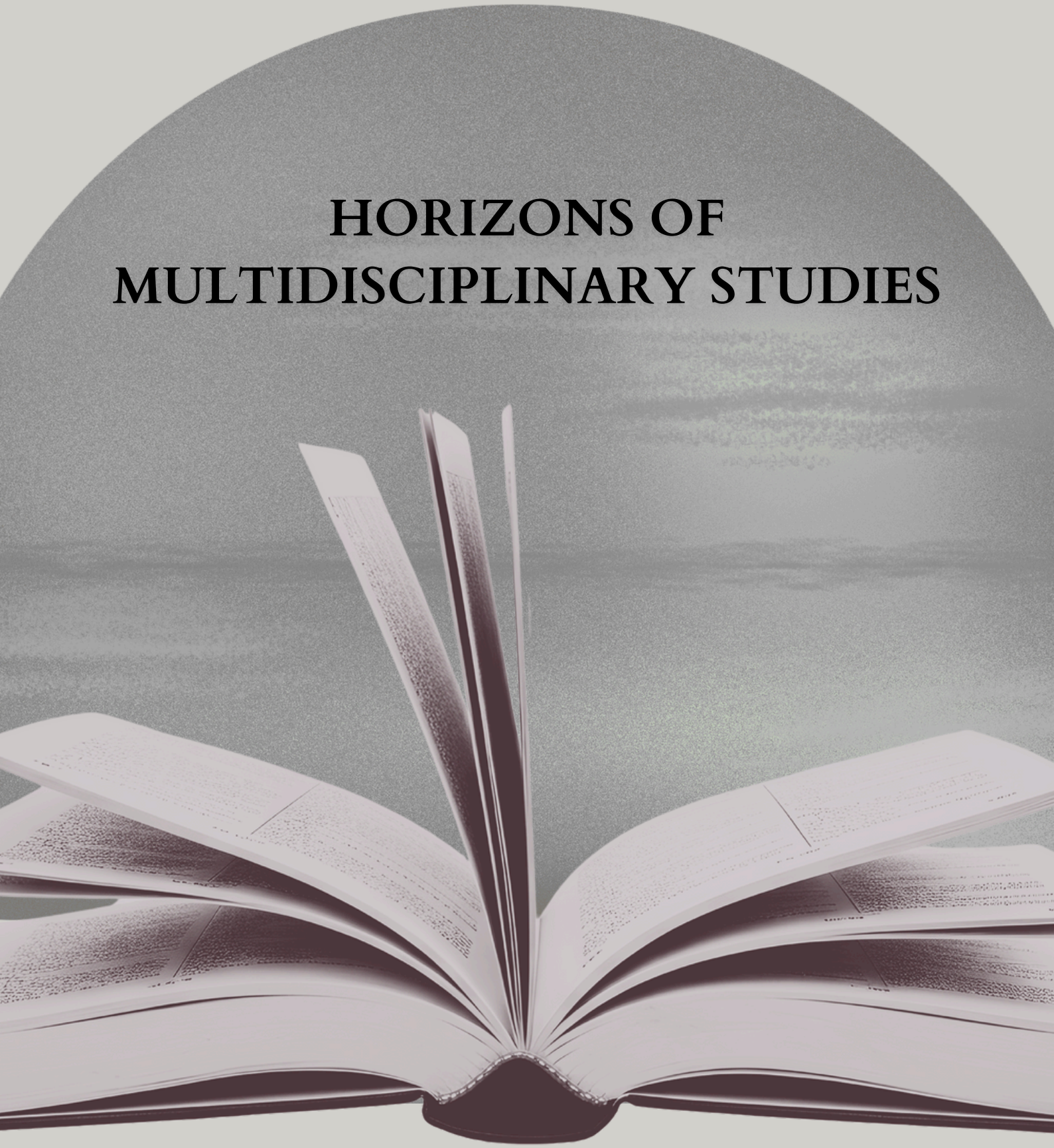
HORIZONS OF MULTIDISCIPLINARY STUDIES



ORGANIZATION
AURUM EDITORA

Aurum
EDITORA

HORIZONS OF MULTIDISCIPLINARY STUDIES



ORGANIZATION
AURUM EDITORA

AURUM EDITORA LTDA - 2025
Curitiba – Paraná - Brasil

EDITOR-IN-CHIEF
Lucas Gabriel Vieira Ewers

BOOK ORGANIZER
Aurum Editora Ltda

TEXT EDITING
Stefanie Vitoria Garcia de Bastos

ART EDITION
Aurum Editora Ltda

COVER IMAGES
Canva Pro, Freepik

LIBRARIAN
Maria Alice Ferreira

AREA OF KNOWLEDGE
Multidisciplinary

The author is solely responsible for the content, accuracy, and veracity of the data presented in this text, which does not necessarily reflect the official position of the Publisher. The work may be downloaded and shared, provided that credit is given to the author, but modification of the content in any way or its use for commercial purposes is not permitted.

All manuscripts underwent a blind peer review by members of the Editorial Board and were approved for publication based on criteria of impartiality and academic objectivity.

Aurum Editora is committed to maintaining editorial integrity at all stages of the publication process, preventing plagiarism, fraudulent data or results, and ensuring that financial interests do not affect the ethical standards of the publication. Any suspicion of scientific misconduct will be investigated with attention to ethical and academic principles.

International Cataloguing in Publication (CIP) Data (Brazilian Book Chamber, São Paulo, Brazil)

Horizons of multidisciplinary studies [e-book]
/ organization Aurum Editora. --
1. ed. -- Curitiba, PR : Aurum Editora, 2025.
PDF

Various authors.
ISBN 978-65-83849-24-3

1. Knowledge 2. Education - Research
3. Integrated teaching 4. Educational innovations
5. Interdisciplinarity in education

25-317855.0 CDD-370.1

Indexes for systematic catalog:

1. Interdisciplinarity: Education 370.1

Maria Alice Ferreira - Librarian - CRB-8/7964

Aurum Editora Ltda
CNPJ: 589029480001-12
contato@aurumeditora.com
(41) 98792-9544
Curitiba - Paraná

PUBLISHER'S STATEMENT

Aurum Editora DECLARES, for the purposes of rights, obligations, and legal or methodological aspects, that:

This publication represents only a temporary transfer of copyright, granting the right to publish and reproduce the materials. The Publisher assumes no responsibility for the authorship of the published manuscripts, in accordance with the provisions of the Copyright Law (Law 9610/98), Article 184 of the Penal Code, and Article 927 of the Civil Code. The author(s) are solely responsible for ensuring compliance with copyright issues and other legal aspects, exempting the Publisher from any civil, administrative, or criminal liability that may arise.

The authors are authorized to DISCLOSE THE WORK in lectures, courses, events, media and television programs, provided that due recognition of authorship and editing is given, without commercial purposes, and that CREDITS to Aurum Editora are duly presented. The omission or exclusion of this information will be the responsibility of the author(s) and the publisher.

All e-books are open access, therefore they should not be sold on websites, e-commerce platforms, or any other medium, whether virtual or physical. Thus, there is no transfer of copyright to the authors, since the format does not generate any rights other than the educational and advertising uses of the work, which can be accessed at any time.

All members of the Editorial Board are volunteers and hold undergraduate or graduate degrees in their respective fields.

Aurum Editora does not authorize the sale or sharing of authors' names, emails, or any other personal data, except for the dissemination of this work, in accordance with the Brazilian Civil Rights Framework for the Internet, the General Data Protection Law, and the Constitution of the Federative Republic.

AUTHOR'S STATEMENT

The author of this work DECLARES, for the following purposes, that:

He/she has no commercial interest that could generate conflict in relation to the published content;

He/she declares to have been actively involved in the preparation of the manuscript, preferably in the following stages: Development of the study, and/or data collection, and/or data analysis and interpretation, writing of the article or review to ensure the intellectual relevance of the material, and final approval of the manuscript for submission;

Certifies that the published text is completely free of falsified data or fraudulent results, as well as flaws related to authorship;

Confirms that it has correctly cited and properly referenced all data and interpretations from other research;

Acknowledges that all sources of funding that may have been received to conduct the research have been properly declared;

Authorizes the editing of the work, including catalog records, ISBN, DOI, and other indexers, graphic design and cover creation, internal layout, as well as the launch and dissemination in accordance with the criteria established by Aurum Editora.

AUTHORS

Alessandro Martins Ribeiro
Amauri Pereira de Souza
Ana Cristina Magalhães Mesquita
Anna Beatriz de Oliveira Sousa
Antônia Marciana Santos Ribeiro
Beto Cherles Coral Rodrigues
Bruna Angélica Strunkis
Daionny Diniz de França Vasconcelos
David Aguiar
Drieli Oliveira Silva
Everson Reili de Souza Teles
Fernanda Barrozo Oliveira
Gabrielle de Almeida Cavalcante
Geovana Lissa Marques Alencar Silverio
Gerismar Cardoso Silva
Glenda Paula Silva Borges
Ingred da Silva Noleto
Jairo Bastidas
Katelaine Maria Mantuam
Letícia Glória Alves
Márcia Ferreira Sales
Marcia Viviane de Araújo Sampaio
Poliana Cardoso Martins
Rodrigo Thomé de Moura
Rosângela Thomé da Silva
Sara Janai Corado Lopes
Solange Pereira Glória
Terciane Soares de Oliveira

SUMMARY

ISBN: 978-65-83849-24-3

Aurum EDITORA

CHAPTER 1

ASSESSMENT OF THE IMPACTS OF ENVIRONMENTAL LEGISLATION ON THE EFFECTIVENESS OF PUBLIC POLICIES

https://doi.org/10.63330/aurumpub.021-001

Fernanda Barrozo Oliveira[1]

ABSTRACT

This study aims to analyze the impacts of environmental legislation on the effectiveness of Brazilian public policies, investigating whether the extensive existing normative framework has translated into concrete results for environmental protection and the promotion of sustainable development. The research, qualitative in nature and bibliographic in character, is based on a theoretical-interpretative analysis of the main laws, policies, and environmental management instruments, as well as their relationship with governance and sustainability. Authors such as Milaré, Fiorillo, Antunes, Freitas, Barbieri, and Sachs were considered, in addition to international documents such as the Rio Declaration (1992) and the UN 2030 Agenda (2015). The results indicate that, although Brazil has one of the most advanced environmental legislations in the world, challenges persist related to institutional fragmentation, lack of resources, insufficient enforcement, and the influence of economic interests on environmental decisions. It is concluded that the effectiveness of legislation depends on the integration between legal norms, public policies, and collaborative governance mechanisms, supported by social participation, transparency, and technological innovation. Thus, institutional strengthening and the adoption of participatory management strategies are essential to transform environmental law into an effective instrument for ecological protection and the promotion of socio-environmental justice.

Keywords: Environmental legislation; Public policies; Sustainability; Environmental governance; Legal effectiveness.

[1] Bachelor's degree in Business Administration, undergraduate student in Environmental and Sanitary Engineering
Estácio University Center of Ribeirão Preto, UniFatecie University Center

INTRODUCTION

The growing degradation of ecosystems and the intensification of climate change have placed the environment at the center of global discussions on development and sustainability. In this context, environmental legislation and public policies emerge as fundamental instruments to guide state and social action in preserving natural resources and promoting a balanced development model. Assessing the impacts of environmental legislation on the effectiveness of public policies thus becomes an essential field of study to understand whether legal and regulatory norms have achieved their objectives and contributed, in fact, to improving environmental and social conditions.

Specialized literature, represented by authors such as Milaré (2020), Fiorillo (2019), and Antunes (2019), highlights that Brazilian Environmental Law has one of the most comprehensive frameworks in the world, consolidated by fundamental milestones such as the 1988 Federal Constitution, Law No. 6,938/1981, which establishes the National Environmental Policy (PNMA), and the New Forest Code (Law No. 12,651/2012). However, despite legal solidity, gaps persist in the implementation and enforcement of these norms, reflecting a distance between legal theory and effective practice. Authors such as Freitas (2020) and Sánchez (2021) emphasize that assessing the effectiveness of environmental legislation means understanding not only the formal compliance with laws but also their concrete impacts on ecosystems, public policies, and society.

The general objective of this study is to analyze the impacts of environmental legislation on the effectiveness of Brazilian public policies, identifying the extent to which existing norms have contributed to environmental protection and sustainable development. Specifically, it seeks to: (a) understand the historical and conceptual evolution of environmental legislation in Brazil; (b) discuss environmental public policies and their management instruments; (c) examine governance and sustainability mechanisms; (d) assess the effects and limitations of environmental legislation; and (e) present future perspectives for improving national environmental policy.

The central hypothesis of this study assumes that Brazilian environmental legislation, although advanced in normative terms, faces difficulties in implementation due to institutional, political, and economic barriers that compromise the uniform application of norms and reduce their positive impact on public policies. It is also assumed that the absence of systematic monitoring, the lack of technical resources, and the lack of integration among federative entities weaken environmental governance and limit the reach of sustainability actions.

The justification for conducting this work stems from the need to understand the factors that influence the effectiveness of environmental policies at a historical moment when ecological challenges are intensifying. The degradation of biomes, the advance of deforestation, urban pollution, and environmental disasters—such as those that occurred in Mariana/MG and Brumadinho/MG—highlight

the urgency of improving legal and administrative mechanisms for control, enforcement, and accountability. Furthermore, the critical analysis of environmental legislation provides a basis for formulating more effective policies and contributes to strengthening democratic and participatory governance.

Methodologically, the study is qualitative and bibliographic in nature, based on a review of specialized literature, legislation, institutional documents, and national and international reports. Reference works in the fields of Environmental Law, public management, and sustainability were consulted, such as those by Barbieri (2017), Jacobi (2003), Bursztyn and Bursztyn (2012), Leff (2001), and Sachs (2008), in addition to official UN documents (1992, 2015) and relevant Brazilian legislation.

The structure of this work is organized into five main sections. The first presents Brazilian environmental legislation from a historical and conceptual perspective, highlighting its normative milestones and fundamental principles. The second discusses environmental public policies, their instruments, and the role of different actors in implementing and evaluating actions. The third addresses environmental governance and sustainability as essential dimensions for consolidating a balanced and participatory development model. The fourth section analyzes the assessment of the impacts of environmental legislation, examining the expected and actual effects of norms and the relationship between legal norms and practical effectiveness. The fifth and final section deals with the challenges, limitations, and future perspectives of applying environmental legislation, reflecting on possible paths for strengthening public policies and ecological governance in Brazil.

Thus, this study seeks to contribute to the academic and political debate on the role of environmental legislation in building a sustainable, transparent, and socially responsible State, in which environmental protection is understood not as an obstacle to development but as an indispensable condition for the continuity of life and social justice.

METHODOLOGY

This research is characterized as a qualitative study, exploratory and descriptive in nature, grounded in bibliographic review and theoretical-interpretative analysis. The choice of this methodology is justified by the need to comprehensively and critically understand the relationships between environmental legislation and the effectiveness of public policies, analyzing not only the normative content of laws but also the political, institutional, and social context in which they are embedded.

The bibliographic review was developed through the analysis of books, scientific articles, legislation, official reports, and national and international institutional documents, encompassing both classical and contemporary authors in the fields of Environmental Law, sustainability, and public policies. Among the main references consulted are Milaré (2020), Antunes (2019), Fiorillo (2019), Freitas (2020),

Barbieri (2017), Bursztyn and Bursztyn (2012), Sánchez (2021), and Jacobi (2003), in addition to legal frameworks such as Law No. 6,938/1981 (National Environmental Policy), Law No. 9,605/1998 (Environmental Crimes Law), and Law No. 12,651/2012 (Forest Code).

The theoretical-interpretative analysis involved consulting norms, resolutions, treaties, and international declarations, such as the Rio Declaration on Environment and Development (1992), the Paris Agreement (2015), and the UN 2030 Agenda (2015), which guide the formulation of environmental policies in the global context. This approach allowed correlating the Brazilian legal framework with international trends in sustainability and environmental governance.

The methodology was structured into complementary stages. First, a theoretical and legal survey was conducted on the evolution of environmental legislation, its principles, and management instruments. Next, an interpretative analysis of environmental public policies and their governance mechanisms was developed, identifying barriers and potentialities. Finally, a critical evaluation of the effectiveness of legislation was carried out, considering indicators such as enforcement, transparency, social participation, and the socio-environmental impact of norms.

The adopted method enabled an interdisciplinary approach, integrating legal, administrative, and ecological aspects essential for understanding the complexity of environmental policy. In this way, the research contributes not only to the academic field but also to the formulation of strategies that improve the application of legislation and strengthen sustainability as a structuring principle of Brazilian public policies.

DEVELOPMENT

ENVIRONMENTAL LEGISLATION: HISTORICAL AND CONCEPTUAL CONTEXT

Brazilian environmental legislation is the result of a long historical process of social, economic, and political transformations, marked by growing awareness of the need to protect the environment and ensure sustainable development. The historical context of environmental protection in Brazil reveals a trajectory that moves from an exploitative and utilitarian view of natural resources to a more integrated and sustainable approach, following the advancement of environmental discussions on the international stage.

During the colonial and imperial periods, Brazilian environmental norms were sparse and primarily aimed at economic exploitation. The first regulatory measures had a patrimonial character and sought to protect the interests of the Crown, such as the Regimento do Pau-Brasil (1605) and the Ordenações Filipinas, which punished tree cutting without authorization. There was, therefore, no genuine ecological concern, but rather economic and administrative interests (Machado, 2013). With the advance of industrialization and accelerated urbanization in the 20th century, environmental degradation increased,

and consequently, the debate on the need for specific norms to control pollution and ensure the rational use of natural resources intensified.

From the 1970s onward, influenced by the Stockholm Conference on the Human Environment (1972)—the first major international milestone of modern environmental policy—Brazil began to structure its environmental legislation more solidly. As a reflection of this conference, the Special Secretariat for the Environment (SEMA) was created in 1973, a precursor to the current Ministry of the Environment, responsible for formulating environmental public policies. This period was also marked by the approval of important laws, such as Law No. 6,938/1981, which established the National Environmental Policy (PNMA), setting principles, objectives, and environmental management instruments, as well as creating the National Environmental System (SISNAMA) and the National Environmental Council (CONAMA). This legislation was a watershed moment, introducing concepts of prevention, control, and environmental responsibility (Antunes, 2019).

Another essential milestone occurred with the 1988 Federal Constitution, considered one of the most advanced in the world in environmental matters. Article 225 enshrined the right of all to an ecologically balanced environment, imposing on the government and society the duty to defend and preserve it for present and future generations. The Constitution also established that liability for environmental damage is strict, requiring full reparation of harm (Brazil, 1988). This advance represented the consolidation of the principle of sustainable development, reconciling economic growth with environmental preservation.

In parallel, international legal frameworks greatly influenced the formulation of Brazilian policies. The United Nations Conference on Environment and Development (Rio-92) reaffirmed global commitments and gave rise to important documents, such as Agenda 21 and the Rio Declaration on Environment and Development, which emphasize international cooperation and common but differentiated responsibilities among nations (UN, 1992). Later, treaties such as the Kyoto Protocol (1997) and the Paris Agreement (2015) reinforced the global commitment to reducing greenhouse gas emissions and addressing climate change. At the national level, legislation such as the Environmental Crimes Law (Law No. 9,605/1998) and the New Forest Code (Law No. 12,651/2012) improved mechanisms for control, penalties, and environmental recovery, evidencing the legal and institutional maturation of Brazilian environmental policy (Milaré, 2015).

The fundamental principles of Environmental Law are pillars that guide the interpretation and application of environmental legislation. Among them are the principle of prevention, which seeks to avoid environmental damage before it occurs; the precautionary principle, which recommends adopting protective measures even in the face of scientific uncertainty; the polluter-pays principle, according to which the agent causing environmental degradation must bear the costs of remediation; and the principle

of the socio-environmental function of property, which links land use to collective interest and environmental preservation (Benjamin, 2008; Fiorillo, 2018). There is also the principle of intergenerational solidarity, which emphasizes the need to ensure dignified living conditions for future generations, and the principle of information and participation, which guarantees society the right to participate in the formulation and control of environmental policies.

Therefore, the evolution of environmental legislation in Brazil reflects not only the State's maturation in addressing ecological challenges but also the incorporation of ethical and social values that transcend the legal dimension. It is a dynamic normative field, constantly updated in the face of global technological, climatic, and socioeconomic transformations. The consolidation of environmental law principles and the integration of national and international legal frameworks have been fundamental for strengthening environmental governance and advancing ecological awareness that recognizes the environment as a common heritage of humanity.

ENVIRONMENTAL PUBLIC POLICIES: CONCEPTS AND PURPOSES

Environmental public policies constitute an articulated set of actions, guidelines, and instruments formulated by the State, in partnership with various sectors of society, with the objective of protecting, conserving, and restoring the environment, ensuring the sustainable use of natural resources and the right of present and future generations to an ecologically balanced environment. According to Jacobi (2003), these policies arise from the need to address environmental problems in a systemic and integrated manner, overcoming the fragmented vision that historically characterized governmental actions in the environmental field. Thus, environmental public policies are conceived as strategies of state intervention, based on normative and scientific principles, aimed at regulating human activities and promoting sustainable practices.

The definition and characteristics of these policies are closely related to the notion of sustainable development and the pursuit of harmonization between economic growth, social justice, and environmental preservation. According to Milaré (2015), environmental policy should act as an instrument for the realization of environmental rights guaranteed by the 1988 Federal Constitution, especially in Article 225, which enshrines a balanced environment as a fundamental right. This policy is characterized by its transversal and intersectoral nature, involving multiple dimensions—ecological, economic, social, legal, and cultural—and requiring cooperation among different levels of government and sectors of society. Furthermore, environmental policies have a preventive, participatory, and educational character, grounded in principles such as precaution, responsibility, and the polluter-pays principle (Antunes, 2019).

For these policies to be effective, the use of appropriate implementation and evaluation instruments is indispensable. Law No. 6,938/1981, which established the National Environmental Policy (PNMA), set forth a series of mechanisms that guide environmental management in Brazil, such as environmental licensing, environmental impact assessment (EIA), ecological-economic zoning (ZEE), environmental information systems, pollution control, and the creation of conservation units. These instruments aim to enable the planning, execution, and monitoring of public and private actions, ensuring compatibility between development and environmental protection (Brazil, 1981).

The evaluation of environmental policies, in turn, is an essential element for measuring their effectiveness and correcting distortions. According to Sánchez (2013), strategic environmental assessment (SEA) and continuous monitoring of the impacts of policies and programs allow for the improvement of environmental management, providing technical and scientific support for decision-making. Transparency and social participation are also fundamental instruments of control and democratization of environmental policy, ensuring that collective interests prevail over short-term economic pressures.

Regarding the role of public and private actors, environmental policies result from a complex network of interactions. The State, through its executive, legislative, and judicial branches, has the duty to formulate, regulate, and oversee the implementation of these policies, ensuring compliance with legislation and access to environmental justice (Freitas, 2020). Federative entities—Union, States, and Municipalities—share competencies in environmental management, as provided in Article 23 of the Federal Constitution, which requires federative cooperation and institutional coordination.

On the other hand, the private sector plays an equally relevant role, whether by adapting its production processes to sustainability standards or by adopting socio-environmental responsibility practices. According to Barbieri (2017), the incorporation of the environmental variable into business management has ceased to be merely a legal requirement and has become a competitive and reputational advantage. Private initiatives can contribute with technological innovations, investments in clean energy, and circular economy practices, reinforcing the transition to a sustainable development model.

Civil society, non-governmental organizations, and social movements also occupy a strategic position in the formulation and control of environmental public policies, acting as mediators between the State and the community. For Acselrad (2009), the effectiveness of environmental policies depends on social engagement and the construction of an environmental citizenship culture that recognizes the interdependence between natural systems and social dynamics. Thus, the democratization of environmental policy is not limited to formal consultation but involves expanding popular participation and strengthening environmental governance.

In summary, environmental public policies constitute a dynamic, multidisciplinary, and constantly evolving field. Their primary purpose is to ensure the
ecological integrity of the planet, reconciling development and sustainability. The consolidation of these policies requires not only the existence of effective legal and institutional instruments but also the ethical and political commitment of all actors involved—State, companies, and civil society—in defending a common good essential to life: the environment.

ENVIRONMENTAL GOVERNANCE AND SUSTAINABILITY

Environmental governance represents one of the fundamental pillars for the implementation of sustainability policies, constituting a set of mechanisms, processes, and institutions through which the public sector, private sector, and civil society make decisions and implement actions aimed at environmental protection and the rational use of natural resources. According to Lemos and Agrawal (2006), environmental governance goes beyond state control, encompassing a broad network of actors and instruments that collaborate in the formulation, execution, and monitoring of environmental policies. It is, therefore, a management model that values democratic participation, interinstitutional cooperation, and transparency as essential conditions for ensuring sustainability.

Public governance and social participation are inseparable dimensions in this context. The 1988 Federal Constitution enshrined democratic management as a principle of public administration, especially in Article 225, by recognizing the environment as a common good and a shared responsibility between the government and society. Thus, social participation is not only a right but also a civic duty that strengthens social control and the legitimacy of political decisions. According to Jacobi (2003), participatory environmental governance implies a continuous process of dialogue, consensus-building, and mediation of socio-environmental conflicts, enabling citizens to influence decisions that directly impact their communities and ecosystems.

Environmental councils, national environmental conferences, public hearings, and sustainability forums are concrete examples of participatory instruments that integrate public environmental governance. These spaces allow articulation between the State and civil society, promoting pluralism and shared responsibility in the management of natural resources. For Bursztyn and Bursztyn (2012), effective environmental governance depends on institutional arrangements that reconcile divergent interests and ensure transparency of actions, preventing decisions from being captured by specific economic or political groups.

Sustainability, in turn, constitutes the guiding principle of environmental public policies and the central axis of contemporary governance. According to the Brundtland Report (1987), sustainability means meeting present needs without compromising future generations, which requires integrated

policies of an economic, social, and ecological nature. In the governance field, this implies adopting a systemic vision of development, incorporating criteria of equity, efficiency, and ecological prudence.

According to Sachs (2008), sustainability should guide not only environmental policies but the entire structure of public planning, ensuring that ecosystem preservation goes hand in hand with combating social inequalities and promoting environmental citizenship.

Thus, sustainable environmental governance requires long-term strategic planning, socio-environmental performance indicators, and continuous evaluation mechanisms. The State must adopt evidence-based policies, integrating technical and traditional knowledge, while the private sector needs to assume commitments to socio-environmental responsibility, aligning with the Sustainable Development Goals (SDGs) of the UN 2030 Agenda (UN, 2015).

Another essential aspect of environmental governance is transparency, social control, and accountability—concepts that interrelate and ensure the legitimacy and effectiveness of public management. Transparency means public access to information about policies, programs, expenditures, and environmental results, allowing society to monitor government actions. According to Souza Filho and Magalhães (2018), environmental transparency strengthens democratic control, reduces corruption, and increases social trust in institutions.

Social control complements this process, enabling society to oversee and evaluate the performance of public and private bodies in implementing environmental policies. Mechanisms such as transparency portals, ombudsman offices, councils, and open data platforms expand citizen participation and consolidate a culture of collective responsibility. Accountability, according to Pinho and Sacramento (2009), refers to the obligation to provide accounts—not only formally but ethically and participatively—regarding the use of public resources and the results achieved.

Thus, environmental governance and sustainability complement each other as structuring dimensions of a public management model that seeks to balance efficiency, ethics, and equity. The effectiveness of this model depends on consolidating a political culture oriented toward cooperation, transparency, and shared social responsibility. In a global scenario marked by climate crises, environmental degradation, and socioeconomic inequalities, strengthening environmental governance means reaffirming the commitment to a sustainable, democratic, and just future for all.

ASSESSMENT OF THE IMPACTS OF ENVIRONMENTAL LEGISLATION

The assessment of the impacts of environmental legislation is an essential instrument for understanding the effectiveness of norms and policies aimed at environmental protection, allowing measurement of the extent to which legal intentions translate into concrete results in the socio-environmental reality. It is an analytical process that seeks to identify, measure, and interpret the expected

and actual effects of environmental legislation on territory, ecosystems, and human populations, contributing to the continuous improvement of public management and environmental regulation. According to Sánchez (2013), impact assessment is not limited to analyzing specific projects but also encompasses examining the consequences of policies and legal frameworks, providing technical and scientific support for more informed and sustainable decisions.

The methods and indicators for evaluating environmental public policies vary according to the objectives and scope of the analyses. In general, the evaluation seeks to answer three central questions: what was planned, what was implemented, and what results were obtained. According to Arretche (1998), the evaluation of public policies should combine quantitative and qualitative methods to understand both measurable results and institutional and social aspects that influence their implementation. In the environmental field, the most commonly used performance indicators involve the reduction of pollutant emissions, sustainable use of natural resources, recovery of degraded areas, compliance with environmental standards, and the degree of social participation in decision-making processes.

The National Environmental Policy (Law No. 6,938/1981) establishes mechanisms for evaluation and control, such as environmental licensing and environmental impact assessment (EIA), which aim to anticipate, mitigate, and monitor the effects of potentially polluting activities. These instruments allow the State and society to monitor compliance with legislation and verify its effectiveness in protecting natural resources. According to Barbieri (2017), the effectiveness of environmental policies depends not only on the quality of norms but also on the institutional capacity of public agencies to apply, enforce, and adjust them according to socio-economic and ecological changes.

The expected and actual effects of environmental legislation do not always converge. In theory, Brazilian environmental legislation is considered one of the most advanced in the world, especially after the 1988 Federal Constitution, which enshrined an ecologically balanced environment as a fundamental right and a duty of the State and society (Art. 225). However, in practice, many of the objectives set forth in law are not fully achieved. According to Milaré (2015), implementation difficulties stem from factors such as institutional fragmentation, insufficient human and financial resources, overlapping competencies, and lack of integration among federal, state, and municipal levels.

Furthermore, Fiorillo (2019) highlights that the gap between expected effects and actual results is related to the low effectiveness of enforcement policies and the persistence of predatory economic practices that still prioritize profit over environmental conservation. Cases such as illegal deforestation, environmental disasters involving dams, and urban pollution show that the mere existence of legal norms does not guarantee compliance. Hence the importance of continuous monitoring mechanisms and participatory evaluation, involving civil society, universities, non-governmental organizations, and the productive sector in analyzing impacts and proposing improvements.

The relationship between legal norms and practical effectiveness is one of the main challenges of contemporary environmental law. The legal system establishes principles, rules, and sanctions, but its effectiveness depends on external factors such as the administrative capacity of the State, the political commitment of managers, and the level of social awareness. According to Freitas (2020), the effectiveness of environmental norms is conditioned by ecological governance, that is, the integration of law, ethics, and politics in promoting sustainable development. It is not enough to create strict laws; it is necessary to ensure their coherent application, with control mechanisms and democratic participation.

Thus, the assessment of the impacts of environmental legislation should be understood as a permanent process of institutional and social learning. It enables the identification of gaps between norms and reality, adjustment of policies, improvement of management instruments, and strengthening of the credibility of public institutions. According to Cunha and Coelho (2020), transparency and access to reliable environmental data are indispensable conditions for accountability and for building a sustainability culture based on evidence.

CHALLENGES AND LIMITATIONS OF APPLYING ENVIRONMENTAL LEGISLATION

The challenges and limitations of applying environmental legislation in Brazil and worldwide reflect the complexity of balancing economic growth, social justice, and ecological preservation in a context marked by structural inequalities and conflicting interests. Although the country has a robust legal framework—consolidated by the 1988 Federal Constitution, the National Environmental Policy (Law No. 6,938/1981), and a series of complementary norms—the enforcement of these laws faces numerous institutional, political, and economic barriers that hinder their full and continuous application. According to Milaré (2015), Brazil lives with a paradox: it has one of the most advanced environmental legislations in the world but faces some of the greatest difficulties in ensuring its practical implementation and social effectiveness.

Institutional barriers manifest primarily in the fragmentation of environmental management among different levels of government and public agencies. While decentralization of environmental policy is necessary to address regional specificities, it often results in overlapping competencies, communication gaps, and excessive bureaucracy. According to Carvalho (2018), this institutional disarticulation compromises the coherence of actions and reduces the State's capacity to respond to environmental emergencies such as wildfires, deforestation, and water contamination. Added to this are shortages of technical personnel, budgetary limitations of environmental agencies, and the precariousness of enforcement structures, which weaken policy implementation and hinder the accountability of violators.

On the political level, challenges arise largely from the influence of economic interests and the volatility of government agendas. Environmental issues are often treated as secondary during economic crises, when policies favor production and consumption incentives. According to Zhouri and Laschefski (2010), environmental policies face strong pressure from business sectors and agribusiness, which seek to relax licensing norms and reduce restrictions on resource exploitation, evidencing the predominance of a developmentalist rationality over an ecological one. This political instability compromises the continuity of environmental policies and weakens the State's role as mediator of conflicts between economy and nature.

From an economic perspective, the application of environmental legislation faces limitations stemming from the unequal distribution of resources and capacities among federative entities and companies. While large corporations can more easily adapt to environmental requirements, small producers and municipalities with low revenue often lack technical and financial support to comply with the law. Barbieri (2017) highlights that, in many cases, the cost of implementing clean technologies and environmental control systems is still perceived as an obstacle, especially in economies dependent on extractive activities and low value-added production. This asymmetry reinforces inequalities and contributes to maintaining unsustainable patterns of production and consumption.

Another set of challenges relates to enforcement, monitoring, and compliance with environmental norms—fundamental elements for the effectiveness of public policies. Environmental enforcement, carried out by agencies such as IBAMA and state environmental institutes, is constantly hampered by budget cuts, insufficient personnel, and political interference. According to Fiorillo (2019), ineffective enforcement undermines the preventive nature of legislation and fosters impunity, as the perception that the risk of punishment is low leads to the recurrence of illegal practices such as deforestation and industrial pollution.

Environmental monitoring also faces technological and operational obstacles. Although advances in remote sensing systems and public databases have expanded the capacity to track environmental changes, there are still gaps in information integration and transparency of results. Sánchez (2013) emphasizes that monitoring should be understood not only as data collection but as part of a continuous cycle of management and evaluation capable of supporting corrective and preventive policies. However, the lack of continuity in actions and the absence of standardized indicators hinder long-term monitoring and policy comparison.

Finally, conflicts between economic development and environmental preservation constitute perhaps the greatest challenge to the effective application of legislation. Historically, Brazil's development model has been based on intensive exploitation of natural resources as a means of driving economic growth. This paradigm, according to Leff (2001), reflects a productivist and anthropocentric

rationality that views nature merely as an instrument of progress and ignores its ecological limits. This vision results in contradictory policies that seek simultaneously to expand production and protect the environment without achieving a real balance between both goals.

In many regions, especially in the Amazon and Cerrado, there is a coexistence of rigid legal frameworks and predatory economic practices, evidencing the gap between sustainability discourse and territorial reality. Bursztyn and Bursztyn (2012) argue that overcoming this contradiction requires rethinking the very concept of development, incorporating ethical, social, and ecological values to reconcile economic prosperity with environmental integrity.

CONCLUSION

The analysis of the impacts of environmental legislation on the effectiveness of public policies demonstrates that Brazil possesses one of the most advanced legal frameworks in the world in environmental matters, the result of a historical process that consolidated principles such as precaution, prevention, the polluter-pays principle, and intergenerational responsibility. However, it is evident that the mere existence of comprehensive laws has not been sufficient to guarantee their full effectiveness, due to institutional, economic, and political obstacles that compromise the implementation and enforcement of norms.

It was found that, although the National Environmental Policy (Law No. 6,938/1981), the 1988 Federal Constitution, and the Forest Code (Law No. 12,651/2012) have established solid foundations for environmental management, the practical application of these norms still faces significant challenges, such as the lack of integration among federative entities, shortages of human and financial resources, and weaknesses in enforcement mechanisms. As highlighted by Milaré (2020) and Fiorillo (2019), these limitations reduce the effectiveness of policies and undermine the credibility of environmental institutions, creating space for continued ecological degradation and impunity in cases of environmental damage.

Another relevant point identified was the imbalance between sustainability discourse and the practice of economic development. In many sectors, a productivist and anthropocentric vision still prevails, subordinating environmental protection to market interests. This contradiction, according to Leff (2001) and Bursztyn and Bursztyn (2012), reflects the need to rethink the development model adopted, incorporating an ecological rationality that recognizes the planet's limits and promotes socio-environmental justice.

Despite these limitations, important advances have been observed in the field of environmental governance and in the incorporation of instruments for participation and social control. The consolidation of councils, conferences, and mechanisms for public transparency contributes to democratizing

environmental management and expanding citizen oversight of State decisions. Furthermore, the growing use of technological innovations and intelligent monitoring systems, such as those developed by INPE and MapBiomas, has enhanced enforcement capacity and provided valuable support for evidence-based policies.

Given this scenario, it is concluded that the effectiveness of environmental legislation depends less on creating new norms and more on institutional strengthening, federative cooperation, and the consolidation of a culture of sustainability and environmental citizenship. Improving legislation must be accompanied by integrated public policies, collaborative governance mechanisms, and incentives for socio-environmental responsibility in the private sector.

In summary, the challenge lies not only in refining the legal text but in transforming it into an instrument of concrete change, capable of ensuring the preservation of ecosystems, social justice, and the right of future generations to a balanced environment. Only through the integration of the State, society, and private initiative will it be possible to transform the existing extensive legal framework into an effective system of environmental protection, ensuring that sustainable development becomes a reality and not merely a principle.

REFERENCES

1. Acselrad, Henri. Sustentabilidade, democracia e conflitos ambientais [Sustainability, Democracy, and Environmental Conflicts]. Rio de Janeiro: Garamond, 2009.

2. Antunes, Paulo de Bessa. Direito Ambiental [Environmental Law]. 13th ed. Rio de Janeiro: Lumen Juris, 2019.

3. Arretche, Marta. Tendências no estudo sobre avaliação [Trends in the Study of Evaluation]. In: Rico, Elizabeth (ed.). Avaliação de políticas sociais: uma questão em debate [Evaluation of Social Policies: A Matter for Debate]. São Paulo: Cortez, 1998.

4. Barbieri, José Carlos. Gestão Ambiental Empresarial: conceitos, modelos e instrumentos [Corporate Environmental Management: Concepts, Models, and Tools]. 4th ed. São Paulo: Saraiva, 2017.

5. Benjamin, Antonio Herman V. Princípios do Direito Ambiental Brasileiro [Principles of Brazilian Environmental Law]. São Paulo: Revista dos Tribunais, 2008.

6. Brasil. Constituição da República Federativa do Brasil de 1988 [Constitution of the Federative Republic of Brazil of 1988]. Brasília: Senado Federal, 1988.

7. Brasil. Lei nº 6.938, de 31 de agosto de 1981. Dispõe sobre a Política Nacional do Meio Ambiente [Law No. 6,938 of August 31, 1981: Establishes the National Environmental Policy]. Diário Oficial da União, Brasília, 1981.

8. Brasil. Lei nº 9.605, de 12 de fevereiro de 1998. Dispõe sobre as sanções penais e administrativas derivadas de condutas e atividades lesivas ao meio ambiente [Law No. 9,605 of February 12, 1998: Provides for Criminal and Administrative Sanctions for Harmful Environmental Conduct]. Diário Oficial da União, Brasília, 1998.

9. Brasil. Lei nº 12.651, de 25 de maio de 2012. Dispõe sobre a proteção da vegetação nativa [Law No. 12,651 of May 25, 2012: Provides for the Protection of Native Vegetation]. Diário Oficial da União, Brasília, 2012.

10. Bursztyn, Marcel; Bursztyn, Maria Augusta. Políticas públicas e sustentabilidade [Public Policy and Sustainability]. Brasília: Editora Universidade de Brasília, 2012.

11. Carvalho, Vinícius Pinheiro de. Gestão ambiental pública e desafios institucionais no Brasil contemporâneo [Public Environmental Management and Institutional Challenges in Contemporary Brazil]. Revista Brasileira de Políticas Públicas, v. 8, n. 2, p. 45–62, 2018.

12. Cunha, Luciana; Coelho, Leonardo. Avaliação de políticas públicas ambientais: desafios e perspectivas [Evaluation of Environmental Public Policies: Challenges and Perspectives]. Revista Brasileira de Políticas Públicas, v. 10, n. 2, p. 112–130, 2020.

13. Fiorillo, Celso Antonio Pacheco. Curso de Direito Ambiental Brasileiro [Course on Brazilian Environmental Law]. 20th ed. São Paulo: Saraiva, 2019.

14. Freitas, Juarez. Sustentabilidade: Direito ao Futuro [Sustainability: The Right to the Future]. 4th ed. Belo Horizonte: Fórum, 2020.

15. Jacobi, Pedro Roberto. Educação ambiental, cidadania e sustentabilidade [Environmental Education, Citizenship, and Sustainability]. Cadernos de Pesquisa, n. 118, p. 189–205, 2003.

16. Leff, Enrique. Epistemologia ambiental [Environmental Epistemology]. 4th ed. São Paulo: Cortez, 2001.

17. Lemos, Maria Carmen; Agrawal, Arun. Environmental Governance. Annual Review of Environment and Resources, v. 31, p. 297–325, 2006.

18. Machado, Paulo Affonso Leme. Direito Ambiental Brasileiro [Brazilian Environmental Law]. 22nd ed. São Paulo: Malheiros, 2013.

19. Milaré, Édis. Direito do Ambiente: a gestão ambiental em foco [Environmental Law: Environmental Management in Focus]. 12th ed. São Paulo: Revista dos Tribunais, 2020.

20. ONU – Organização das Nações Unidas. Declaração do Rio sobre Meio Ambiente e Desenvolvimento [Rio Declaration on Environment and Development]. Rio de Janeiro: ONU, 1992.

21. ONU – Organização das Nações Unidas. Transformando nosso mundo: a Agenda 2030 para o Desenvolvimento Sustentável [Transforming Our World: The 2030 Agenda for Sustainable Development]. Nova York: ONU, 2015.

22. Pinho, José Antônio G.; Sacramento, Ana Rita. Accountability: já podemos traduzi-la para o português? [Accountability: Can We Translate It into Portuguese Yet?] Revista de Administração Pública, v. 43, n. 6, p. 1343–1368, 2009.

23. Sachs, Ignacy. Caminhos para o desenvolvimento sustentável [Paths to Sustainable Development]. Rio de Janeiro: Garamond, 2008.

24. Sánchez, Luis Enrique. Avaliação de impacto ambiental: conceitos e métodos [Environmental Impact Assessment: Concepts and Methods]. 3rd ed. São Paulo: Oficina de Textos, 2021.

25. Souza Filho, José Antônio de; Magalhães, Patrícia. Transparência e controle social na gestão ambiental pública [Transparency and Social Control in Public Environmental Management]. Revista de Administração Pública, v. 52, n. 4, p. 780–798, 2018.

26. United Nations. Paris Agreement. Paris: UNFCCC, 2015.

27. United Nations. Transforming Our World: The 2030 Agenda for Sustainable Development. New York: UN, 2015.

28. World Commission on Environment and Development (WCED). Our Common Future. Oxford: Oxford University Press, 1987.

29. Zhouri, Andréa; Laschefski, Klemens. Desenvolvimento e conflitos ambientais [Development and Environmental Conflicts]. Belo Horizonte: Editora UFMG, 2010.

ISBN: 978-65-83849-24-3

MARKETING MANAGEMENT AND COMMERCIAL PROCESSES

https://doi.org/10.63330/aurumpub.021-002

Antônia Marciana Santos Ribeiro[1]

ABSTRACT

This paper addresses the topic of Marketing Management and Commercial Processes, emphasizing the importance of marketing, sales management, and technological innovation for strengthening and enhancing the competitiveness of organizations in the current context. The main objective was to analyze how marketing management relates to commercial processes and how the integration of marketing, sales, and technology contributes to business growth. Specifically, the study investigated the concepts and evolution of marketing management, the structure of commercial processes, marketing strategies and competitive positioning, as well as the role of technology and innovation in transforming business practices. The research was developed through a qualitative and descriptive methodology, based on a bibliographic review of classical and contemporary authors in the fields of marketing and management, such as Kotler, Keller, Las Casas, Cobra, and Turban, among others. The theoretical framework enabled an understanding that modern marketing has surpassed the traditional view of promotion and sales, establishing itself as a management philosophy oriented toward value creation and meeting consumer needs. It was found that well-structured and integrated commercial processes allow for greater operational efficiency and closer relationships with customers, fostering loyalty and organizational sustainability. The results also highlighted that technological innovation and the advancement of digital marketing have profoundly transformed consumer behavior and business strategies, promoting new forms of interaction and service personalization. It was concluded that the use of tools such as e-commerce, CRM, and data analysis significantly contributes to more assertive decision-making and strengthens competitiveness in the global market.

Keywords: Marketing management; Commercial processes; Marketing strategies; Technological innovation; Business competitiveness.

[1] Postgraduate studies in Administration
Facprisma
E-mail: toniaribeiro1@hotmail.com

INTRODUCTION

This paper addresses the topic of Marketing Management and Commercial Processes, with the aim of understanding how marketing and commercial management are interconnected in the construction of strategies geared toward organizational success and sustainability. In a globalized, competitive, and constantly evolving economic scenario, companies must quickly adapt to market changes and to the new expectations of consumers, who today are more informed, demanding, and connected. In this context, marketing ceases to be merely a promotional tool and assumes a central role in strategic management, guiding decisions and strengthening the relationship between brands and customers.

Authors such as Kotler and Keller (2012), Las Casas (2019), and Cobra (2020) emphasize that modern marketing has evolved far beyond the mere sale of products, becoming a management philosophy focused on value creation and meeting human needs. This transformation reflects a new way of thinking about marketing management, where the focus is on understanding consumer behavior, segmenting markets, positioning brands, and developing long-term relationships. At the same time, technological innovation and digital transformation, discussed by Kotler, Kartajaya, and Setiawan (2017) and Turban et al. (2021), have profoundly changed the way organizations plan and execute their commercial processes, introducing automation, data analysis, and new platforms for interacting with the public.

The choice of this topic is justified by the need to understand how the integration of marketing, sales, logistics, and technology has become essential for the competitiveness of contemporary companies. In an environment of rapid changes and increasingly digital consumers, understanding commercial processes also means understanding market dynamics and the strategies that ensure organizational survival and growth. Thus, studying marketing management and commercial processes is to reflect on the present and future of business management, in a context where innovation and customer relationships have become strategic differentiators.

The main objective of this study is to analyze the importance of marketing management and commercial processes in modern management, understanding how marketing, technology, and innovation contribute to strengthening companies. More specifically, it seeks to discuss the concepts and historical evolution of marketing management; understand the structure of commercial processes, from planning to sales control; examine marketing strategies and competitive positioning; and finally, analyze the role of technology and innovation in productivity and consumer behavior.

The hypothesis guiding this research is that organizations that integrate marketing strategies with technological innovation and a customer-centric approach achieve better results in terms of efficiency, customer loyalty, and competitive advantage. It is believed that technology, when combined with market knowledge and humanized management, transforms the way companies relate to their audiences

and build value over time.

The methodology used is based on a qualitative bibliographic research, grounded in classical and contemporary authors in the fields of marketing, management, and technology. Reference works by Kotler and Keller (2012), Las Casas (2019), Cobra (2020), Davenport and Harris (2017), and Turban et al. (2021), among others, were consulted, allowing for a broad and updated analysis of the transformations in commercial processes and marketing practices.

This study was developed in a structured manner to provide a comprehensive and integrated view of the topic. Following this introduction, the development is divided into four main parts: the first addresses the concepts of marketing management, highlighting its definition, evolution, and role in organizational management; the second discusses commercial processes and market dynamics, emphasizing the importance of integrating marketing, sales, and logistics; the third analyzes marketing strategies and competitive positioning, exploring tools such as market segmentation, the 4 Ps, and CRM; and the fourth part deals with the role of technology and innovation in commercial processes, emphasizing automation, e-commerce, and the impacts of digital transformation on consumer behavior.

METHODOLOGY

This study was developed through qualitative and descriptive research, based on a bibliographic review of works and studies related to marketing management, commercial processes, and the influence of technology and innovation on business management. The adopted methodology aimed to understand established concepts and practices, as well as to identify their applications in the current organizational context.

Reference authors such as Kotler and Keller (2012), Las Casas (2019), Cobra (2020), Kotler, Kartajaya, and Setiawan (2017), Davenport and Harris (2017), and Turban et al. (2021), among others, were consulted with the objective of providing theoretical support for the analysis. The study was developed in stages that addressed: the concepts of marketing management; the structure and integration of commercial processes; marketing strategies and competitive positioning; and the role of technology and innovation in consumer behavior.

The analysis was conducted in an interpretative manner, seeking to relate the authors' ideas to contemporary organizational practices. Thus, the adopted methodology enabled the construction of an integrated and reflective view of how marketing, combined with innovation and efficient management, contributes to the growth and competitiveness of companies.

DEVELOPMENT

CONCEPTS OF MARKETING MANAGEMENT

Marketing management, also known as marketing administration, is one of the fundamental pillars of modern management, as it seeks to understand and meet consumer needs and desires in a strategic and sustainable manner. Its concept goes far beyond simple sales actions: it involves planning, execution, and control of activities aimed at creating value for the customer and maintaining long-term relationships.

According to Kotler and Keller (2012), marketing can be defined as a social and managerial process through which individuals and groups obtain what they need and want by creating, offering, and exchanging products and services of value with others. This definition broadens the understanding of marketing, positioning it as a management tool that connects the market to organizations, guiding business decisions based on consumer demands and competitive environmental conditions.

Historically, marketing management has undergone significant evolution. In the early 20th century, companies focused on production and sales—periods known respectively as the production era and the sales era. At that time, it was believed that simply manufacturing products on a large scale would ensure consumption, and later, that aggressive sales techniques were sufficient to conquer the market (LAS CASAS, 2019). However, from the second half of the 20th century onward, with increased competition and more demanding consumers, the marketing era emerged, marked by customer centrality and the appreciation of strategies aimed at understanding expectations and behaviors.

Las Casas (2019) reinforces that modern marketing should not be understood merely as a set of techniques, but as a market-oriented management philosophy. This philosophy proposes that the entire company be focused on satisfying the consumer, recognizing that organizational success depends directly on that satisfaction. This perspective is also shared by Cobra (2020), who highlights marketing as a dynamic process of adaptation and innovation, in which the manager must constantly analyze the environment, segment the market, position the product, and develop sustainable relationships with the organization's various audiences.

The role of marketing in organizational management is, therefore, strategic and integrative. According to Kotler and Keller (2012), it connects all areas of the company—production, finance, human resources, logistics—around a common purpose: to generate value for the customer and competitive advantage for the organization. This integration makes marketing an essential tool for planning and decision-making, contributing to the building of strong brands, customer loyalty, and sustainable business growth.

Furthermore, current marketing incorporates new paradigms, such as digital marketing, social marketing, and sustainable marketing, reflecting technological transformations and the ethical demands of contemporary society. Cobra (2020) observes that organizations need to understand these changes and

adapt their strategies, using market intelligence and data as support for more assertive and humanized decisions.

COMMERCIAL PROCESSES AND MARKET DYNAMICS

Commercial processes represent the set of strategic and operational activities that enable organizations to understand, serve, and retain their customers in an increasingly dynamic and competitive market environment. These processes are not limited to the sale of products or services but encompass an entire cycle that begins with the planning of commercial actions and extends to the control and evaluation of the results obtained. In this sense, understanding and properly structuring commercial processes is essential to ensure organizational efficiency, customer satisfaction, and business sustainability.

According to Las Casas (2019), the commercial process should be understood as a system composed of three main stages: planning, execution, and sales control. Planning involves defining sales goals, strategies, and policies, considering aspects such as the target audience profile, brand positioning, and market conditions.

Execution, in turn, entails the practical application of strategies, including customer approach, negotiation, closing of sales, and post-sale service. Sales control serves to monitor team performance, analyze result indicators, and propose adjustments to ensure continuous improvement.

Kotler and Keller (2012) emphasize that the success of these processes depends on the company's ability to integrate its various departments, especially marketing, sales, and logistics. This integration is fundamental because marketing is responsible for understanding the market and generating demand; sales convert that demand into revenue; and logistics ensure that the product reaches the customer quickly, safely, and efficiently. When these areas work in a coordinated manner, they create a continuous value flow that enhances the consumer experience and strengthens the brand image.

Cobra (2020) reinforces that this synergy among departments is one of the main competitive differentiators of modern organizations. In a scenario of intense competition and increasingly demanding consumers, the integration of marketing, sales, and logistics enables rapid responses to market changes, greater personalization in customer service, and reduced operational costs. Moreover, it facilitates the use of information technology tools, such as Customer Relationship Management (CRM) and Enterprise Resource Planning (ERP) systems, which contribute to real-time data control and analysis.

Practical examples demonstrate how well-structured commercial processes directly impact organizational results. Major companies in the retail sector, such as Magazine Luiza and Amazon, are benchmarks in this regard. Both have efficiently integrated marketing, sales, and logistics areas, using digital platforms that allow for personalized offers, optimized deliveries, and continuous customer relationships. This integrated vision makes the commercial process more agile and customer-centered, as

advocated by Kotler and Keller (2012), who emphasize that true competitive advantage lies in creating perceived value for the customer at every stage of the purchasing journey.

MARKETING STRATEGIES AND COMPETITIVE POSITIONING

Marketing strategies and competitive positioning are essential elements for the success and sustainability of organizations in a market characterized by intense competition and increasingly demanding consumers. Through strategic management oriented toward the customer, companies seek to understand the needs and expectations of their target audience, identify opportunities for differentiation, and establish a solid and coherent image in the marketplace. In this context, tools such as market segmentation, the marketing mix, and loyalty strategies become fundamental for building lasting competitive advantages.

According to Kotler and Keller (2012), market segmentation is the process of dividing a broad and heterogeneous market into smaller and more homogeneous groups of consumers who share similar characteristics, behaviors, or needs. This step is essential for organizations to define their target audience—that is, the group of consumers that will be effectively served by their marketing actions. From there, competitive positioning consists of establishing a clear value proposition that differentiates the brand or product from competitors, occupying a unique space in the consumer's mind.

Las Casas (2019) adds that positioning is the result of a strategic and coherent construction over time. It depends not only on advertising communication but also on all points of contact between the company and the customer, from product quality to customer service and the overall consumption experience. Thus, effective positioning reflects the brand's identity and the promise it fulfills to its audience.

One of the pillars for achieving this positioning is the proper use of the marketing mix, also known as the 4 Ps of marketing: product, price, place, and promotion. According to Cobra (2020), the product represents the set of attributes and benefits offered to the consumer; price is the amount the customer is willing to pay in exchange for perceived value; place refers to the distribution and availability of the product; and promotion encompasses the communication strategies that publicize and strengthen the brand. The balance among these elements is what ensures the success of marketing actions and the company's competitiveness.

In recent years, technological evolution and digital transformation have brought new challenges and opportunities to marketing. Loyalty and customer relationship strategies have gained prominence, driven by the use of Customer Relationship Management (CRM) systems. According to Kotler and Keller (2012), CRM allows companies to collect, organize, and analyze information about customer behavior and preferences, enabling more personalized and effective communication. This personalization creates

emotional bonds and strengthens brand loyalty, becoming a competitive differentiator in saturated markets.

Practical examples reinforce the importance of these strategies. Companies such as Natura and Starbucks, for instance, use CRM and relationship marketing to understand consumer behavior, develop personalized campaigns, and offer unique experiences. This humanized approach, as pointed out by Cobra (2020), transforms the customer into a true partner of the brand, promoting trust and long-term engagement.

In summary, marketing strategies and competitive positioning are fundamental for organizations to gain and maintain their place in the market. Proper segmentation, balanced use of the 4 Ps, and loyalty based on relationships and data consolidate a modern marketing management approach that is customer-centered and focused on creating mutual value. As Kotler and Keller (2012) emphasize, true business success lies not only in selling more but in better understanding the consumer and building relationships that endure over time.

THE ROLE OF TECHNOLOGY AND INNOVATION IN COMMERCIAL PROCESSES

Technology and innovation currently play a central role in transforming commercial processes and redefining business strategies. In a globalized and highly connected world, organizations face the challenge of adapting to new market demands and to the behavior of an increasingly digital, informed, and demanding consumer. In this context, automation, e-commerce, digital marketing, and data analysis have become indispensable tools for increasing productivity, enhancing customer experience, and strengthening business competitiveness.

According to Kotler, Kartajaya, and Setiawan (2017), we are living in the era of Marketing 4.0, characterized by the convergence of the physical and digital worlds. This new phase of marketing is driven by digital transformation, which promotes process automation and the intensive use of information and communication technologies. Commercial automation allows companies to optimize routine tasks, reduce operational errors, and free up time for strategic activities such as sales planning and performance analysis. Las Casas (2019) emphasizes that by incorporating technological tools into their routines, companies achieve greater accuracy in demand forecasting, inventory control, and customer relationship management.

The advancement of e-commerce has revolutionized the way commercial transactions are conducted. According to Turban et al. (2021), electronic commerce enables companies of all sizes to reach global markets, operate 24 hours a day, and offer personalized experiences to consumers. Digital platforms such as Amazon, Mercado Livre, and Magalu are examples of how the integration of technology, logistics, and digital marketing redefines customer relationships and creates new forms of

consumption. Additionally, the use of business intelligence (BI) and big data analytics tools has become essential for understanding purchasing behavior, enabling more assertive and data-driven decisions.

Cobra (2020) and Kotler and Keller (2012) observe that digital marketing has significantly expanded the reach and effectiveness of commercial strategies. Through social media, email marketing campaigns, SEO, and targeted advertising, companies can establish direct, interactive, and personalized communication with their audience. This digital proximity creates opportunities to strengthen brand identity and foster customer loyalty, while also enabling real-time performance monitoring.

Data analysis is another factor that has profoundly transformed commercial processes. According to Davenport and Harris (2017), the concept of analytical competition refers to the use of data as a strategic advantage. Companies that master the collection, processing, and interpretation of information can anticipate trends, predict consumer behavior, and quickly adjust their marketing and sales strategies. This analytical capability is now seen as an essential competitive differentiator for sustainable growth.

The impacts of these transformations are broad and go beyond productivity. Consumer behavior has also been profoundly altered. According to Kotler et al. (2021), the new consumer is digital, connected, participative, and seeks personalized experiences. They compare prices, read reviews, share opinions on social media, and expect quick responses from brands. This new profile demands a more empathetic, agile, and transparent approach from companies, reinforcing the importance of relationship-based strategies and added value.

Moreover, the integration of technology and innovation encourages disruptive business models, such as omnichannel, which unifies physical and online shopping
experiences, and social commerce, which transforms social networks into sales channels. These trends demonstrate that technological innovation is not merely a support tool but a strategic engine that redefines how companies operate and interact with their customers.

In summary, technology and innovation in commercial processes represent a paradigm shift in contemporary business management. They not only enhance operational efficiency but also strengthen companies' adaptability in a constantly changing environment. As Kotler, Kartajaya, and Setiawan (2017) affirm, true competitive advantage in the digital world lies in the ability to integrate technology, creativity, and purpose to generate lasting value for customers and society.

CONCLUSION

Marketing management and commercial processes represent fundamental pillars for the strategic management of contemporary organizations. Throughout this study, it was possible to understand that modern marketing goes beyond the traditional view of mere promotion and product sales, assuming an essential role in value creation, customer loyalty, and the building of sustainable relationships. Authors

such as Kotler and Keller (2012), Las Casas (2019), and Cobra (2020) emphasize that marketing is, above all, a management philosophy focused on understanding and satisfying human needs, connecting all areas of the company around a common purpose: generating value for the customer and competitive advantage for the organization.

The theoretical analysis demonstrated that commercial processes play a strategic role within companies, integrating the planning, execution, and control of sales in a coordinated and efficient manner. When well-structured, these processes ensure greater productivity, better resource utilization, and stronger alignment among the marketing, sales, and logistics departments. This integration is indispensable in an increasingly dynamic and competitive market, where the consumer has become the protagonist of the purchasing process and demands personalized, agile, and high-quality experiences.

Throughout the study, the importance of marketing strategies and competitive positioning was also observed as instruments of differentiation and brand strengthening. Market segmentation, target audience definition, and the marketing mix—the 4 Ps (product, price, place, and promotion)—remain the foundations of marketing planning, but are now complemented by new practices such as digital marketing and the use of relationship tools like Customer Relationship Management (CRM). These resources enable companies to gain deeper insights into consumer behavior and offer personalized solutions, fostering bonds of trust and loyalty.

Another essential point addressed in this study was the role of technology and innovation in commercial processes. Automation, e-commerce, digital marketing, and data analysis have revolutionized the way organizations interact with the market and make decisions. As advocated by Kotler, Kartajaya, and Setiawan (2017) and Turban et al. (2021), we are living in the era of Marketing 4.0 and Marketing 5.0, in which technology and humanization coexist as complementary forces. In this context, companies that manage to integrate technological resources with human sensitivity become more adaptable and competitive, offering more meaningful experiences to consumers and contributing to the construction of a more connected and collaborative society.

The research allowed us to conclude that marketing management and commercial processes should not be viewed as isolated areas, but as parts of a single strategic system that drives organizational growth. Business success, therefore, depends on the ability to align marketing, innovation, and management in a coherent and sustainable manner. Companies that invest in technology, understand their audience, and value human relationships are better prepared to face the challenges of the global market and remain competitive in the long term.

In summary, this study reinforces that the true essence of marketing lies in understanding people and building shared value. The combination of technical knowledge, technological innovation, and human sensitivity is what makes it possible to transform strategies into concrete results, strengthening not only

organizations but also the relationships between brands, customers, and society. Thus, marketing management and commercial processes continue to be indispensable instruments for economic, social, and organizational development in the 21st century.

REFERENCES

1. Cobra, Marcos. Administração de marketing no Brasil [Marketing Management in Brazil]. 7th ed. São Paulo: Atlas, 2020.

2. Kotler, Philip; Keller, Kevin Lane. Administração de marketing [Marketing Management]. 14th ed. São Paulo: Pearson Education, 2012.

3. Las Casas, Alexandre Luzzi. Administração de marketing: conceitos, planejamento e aplicações à realidade brasileira [Marketing Management: Concepts, Planning, and Applications to the Brazilian Context]. 10th ed. São Paulo: Atlas, 2019.

4. Davenport, Thomas H.; Harris, Jeanne G. Competing on analytics: the new science of winning. Boston: Harvard Business Press, 2017.

5. Kotler, Philip; Kartajaya, Hermawan; Setiawan, Iwan. Marketing 4.0: do tradicional ao digital [Marketing 4.0: Moving from Traditional to Digital]. Rio de Janeiro: Sextante, 2017.

6. Kotler, Philip; Kartajaya, Hermawan; Setiawan, Iwan. Marketing 5.0: tecnologia para a humanidade [Marketing 5.0: Technology for Humanity]. Rio de Janeiro: Sextante, 2021.

7. Turban, Efraim; Pollard, Carol; Wood, Gregory. Electronic commerce 2021: a managerial and social networks perspective. Cham: Springer, 2021.

ISBN: 978-65-83849-24-3

FROM CONTROL TO IMPROVEMENT: PATHS OF AUDITING IN PUBLIC MANAGEMENT

https://doi.org/10.63330/aurumpub.021-003

Fernanda Barrozo Oliveira[1]

ABSTRACT

Auditing in public management represents a fundamental instrument for strengthening governance and transparency in state administrations. This study aimed to analyze the evolution of public auditing in Brazil, its purposes, and its importance in the continuous improvement of management. The research adopted a qualitative approach, with a bibliographic review of relevant works and documents on the subject. The main results indicated that public auditing evolved from a rigid control model to a process focused on the efficiency and effectiveness of governmental actions. Contemporary auditing not only monitors but also proposes improvements, acting as an agent of transformation in public administration. The conclusions pointed out that, despite advances, auditing faces structural and cultural challenges that limit its effectiveness. Overcoming these challenges is essential to ensure that auditing fulfills its role of promoting accountability and transparency, contributing to a more ethical and efficient public administration.

Keywords: Public auditing; Governance; Transparency; Efficiency; Management.

[1] Bachelor's degree in Business Administration, undergraduate student in Environmental and Sanitary Engineering Estácio University Center of Ribeirão Preto, UniFatecie University Center

INTRODUCTION

Auditing in public management is an increasingly relevant topic, especially in a context where efficiency, transparency, and fiscal responsibility are increasingly demanded by society. This study explored the evolution of public auditing in Brazil, highlighting its importance as an instrument of control and improvement of public administration. The literature consulted encompassed works that discuss auditing as a governance mechanism, emphasizing the transition from a merely punitive approach to a proactive perspective that seeks to contribute to the improvement of administrative processes.

The central objectives of the study were to analyze the concepts and purposes of public auditing, investigate its structure and types, and discuss contemporary challenges faced in this area. The hypothesis raised indicated that public auditing, although it has advanced significantly, still faces barriers that limit its effectiveness and integration with governance principles.

The justification for conducting this study lies in the need to understand auditing as an essential element for promoting accountability and transparency in public management. In a scenario of growing demand for more efficient and ethical public services, it is essential that public administration uses auditing as a tool for learning and transformation.

The development of the work was carried out through qualitative research, based on bibliographic review and document analysis. The research included consultation of standards, manuals, and relevant works, which provided support for understanding the concepts and practices of public auditing. The work was structured in sections that addressed the origin of auditing in Brazil, its contemporary modalities, and culminated in a discussion on future perspectives and challenges faced in the area.

Thus, the study sought to offer a comprehensive view of auditing in public management, emphasizing its importance in building a more transparent, responsible administration committed to the continuous improvement of services provided to society.

METHODOLOGY

The methodology of this study was developed to allow a comprehensive analysis of auditing in public management in Brazil. The approach adopted was qualitative, focusing on exploring concepts, practices, and challenges related to public auditing. The research began with an extensive bibliographic review, consulting works by renowned authors and academic articles, as well as official manuals and documents dealing with auditing standards and practices. This review provided a solid theoretical framework, underpinning the discussions throughout the work.

Next, a document analysis was carried out, including the evaluation of regulatory standards such as the Federal Constitution of 1988 and the Fiscal Responsibility Law (Complementary Law No. 101/2000). This analysis allowed understanding how these guidelines establish principles for public

auditing and fiscal management. Finally, the research included a study of practical cases of audits conducted by control bodies such as the Federal Court of Accounts (TCU). This stage was crucial to illustrate the application of the concepts discussed and highlight the results and impacts of audits on public management.

The research was conducted rigorously, ensuring data collection from reliable sources and the use of analysis methods that guaranteed the objectivity of the information. The work resulted in a critical discussion on current public auditing practices, their challenges, and future perspectives, thus contributing to the understanding and improvement of this important instrument in public administration.

DEVELOPMENT

AUDITING IN THE PUBLIC SECTOR: CONCEPTS AND PURPOSES

Auditing in the public sector has consolidated over time as an essential instrument for strengthening governance, transparency, and administrative efficiency. Its origin dates back to the earliest forms of financial control exercised by States, when the primary concern was to ensure the correct collection and application of public resources. In Brazil, the development of governmental auditing is closely linked to the evolution of the State itself and its control institutions, especially after the Federal Constitution of 1988, which enshrined the principle of publicity and expanded the role of oversight and auditing bodies (Brazil, 1988).

According to Figueiredo and Santos (2018), public auditing emerged as a control practice aimed at verifying the legality and legitimacy of administrative acts, but over time it began to incorporate broader dimensions, such as economy, efficiency, and effectiveness of governmental actions. This transition reflects a paradigm shift: from a merely punitive and compliance-based audit to a modern and proactive audit that seeks to contribute to the improvement of public management. According to the Federal Court of Accounts (TCU, 2021), current governmental auditing is a systematic, independent, and documented process that aims to obtain and evaluate evidence to determine whether the activities, programs, and operations of an entity are being conducted in accordance with principles of good management and governance.

The concept of governmental auditing, therefore, goes beyond simple accounting control. For Rezende and Slomski (2019), it consists of a set of technical procedures aimed at analyzing compliance, performance, and results of public actions, ensuring the proper application of resources and the effectiveness of public policies. Silva and Rezende (2020) argue that auditing in the public sector is an instrument of accountability, that is, a means of ensuring that managers account for

their decisions, promoting transparency and responsibility in administration.

The differences between public and private auditing are substantial and mainly concern the nature of objectives and purposes. While auditing in the private sector aims to ensure the reliability of financial statements and protect the interests of investors and shareholders, public auditing seeks to guarantee the correct application of public resources and compliance with the collective interest (Figueiredo; Santos, 2018). Furthermore, governmental auditing is subject to constitutional principles and public legislation, such as the Fiscal Responsibility Law (Complementary Law No. 101/2000) and the new Public Procurement Law (Law No. 14.133/2021), which reinforce the role of internal and external control as mechanisms of governance and integrity (Brazil, 2000; Brazil, 2021).

In the contemporary context, public auditing assumes multiple objectives. Among the main ones are controlling the legality and legitimacy of administrative acts, evaluating the efficiency and effectiveness of public policies, and continuously improving management and governmental processes. According to the TCU Operational Audit Manual (2021), auditing should provide support for improving administration by identifying flaws and proposing recommendations that contribute to good governance. Thus, auditing is not limited to pointing out irregularities but acts as an instrument of organizational learning and support for public decision-making.

The role of the public auditor in this scenario is of fundamental importance. They must act with independence, impartiality, and technical responsibility, respecting the ethical principles that govern public service. According to the standards of the International Organization of Supreme Audit Institutions (INTOSAI, 2019), auditors should base their actions on integrity, objectivity, professional competence, and commitment to the public interest. Public trust in audit results depends on the ethical conduct and competence of the professionals involved, who must maintain a critical stance and commitment to the values of public administration.

Moreover, the contemporary public auditor is not only an inspector but also an agent of transformation and continuous improvement. For Chiavenato (2014), the efficiency of organizations—public or private—depends on the ability of their agents to identify problems, propose solutions, and promote changes. Thus, modern auditing assumes a pedagogical role by guiding managers on good governance practices and fostering an organizational culture focused on results and transparency.

Therefore, it can be affirmed that auditing in the public sector is an indispensable mechanism for administrative democracy, as it strengthens social control, promotes the rational use of resources, and drives the improvement of services provided to the population. Its evolution from a rigid control instrument to a process of evaluation and management improvement reflects the institutional maturity of the State and its commitment to a more efficient, ethical, and transparent public administration.

STRUCTURE AND TYPES OF AUDITING IN PUBLIC ADMINISTRATION

The structure of auditing in Brazilian public administration is organized into different levels and modalities that complement each other to ensure legality, legitimacy, efficiency, and transparency in state management. This plurality of audits—internal, external, and independent—reflects the need for multiple control mechanisms that, together, guarantee good governance and the rational use of public resources (Figueiredo; Santos, 2018).

Internal auditing is carried out within the organizational structure of the public entity itself, aiming to evaluate internal controls, administrative procedures, and the results achieved by management units. According to the Federal Court of Accounts (TCU, 2021), its main function is to support senior management in preventing errors and irregularities by identifying risks and proposing improvements. Thus, internal auditing assumes a preventive and educational character, acting as a link between management and external control. External auditing, on the other hand, is conducted by autonomous bodies in relation to the audited entity, with the purpose of overseeing the legality and efficiency of public administration. In Brazil, this function is primarily exercised by the Federal Court of Accounts (TCU), State Courts of Accounts (TCEs), and Municipal Courts of Accounts (TCMs), which have constitutional authority to judge the accounts of public administrators and issue prior opinions on the accounts of the head of the Executive branch (Brazil, 1988).

In addition, there is independent auditing, carried out by professionals or specialized firms that do not belong to the public structure but are hired to examine financial statements, evaluate internal controls, or assist oversight bodies in specific analyses. According to Rezende and Slomski (2019), independent auditing, although more common in the private sector, has gained relevance in the public sphere, especially in state-owned enterprises and mixed-capital companies, contributing to greater credibility and transparency of financial reports.

Regarding audit modalities, literature and technical standards distinguish different approaches according to objectives and evaluation criteria. Compliance auditing (or regularity auditing) focuses on verifying whether administrative actions and operations comply with current legal, regulatory, and procedural norms. Accounting auditing, in turn, is dedicated to analyzing financial statements and accounting records, seeking to ensure that the data reflected in accounting accurately represent the entity's financial and patrimonial situation (CFC, 2016).

Operational auditing and performance auditing constitute more modern modalities aimed at evaluating the efficiency, effectiveness, and impact of public policies and programs. According to TCU (2021), operational auditing seeks to analyze management performance from a results perspective, identifying causes of deficiencies and proposing recommendations for improvement. This type of audit is based on principles of good governance and results-based management, aligning with the international

trend of using auditing as a tool for continuous improvement, as advocated by INTOSAI (2019) in its ISSAI 3000 standards.

The main oversight bodies responsible for executing and supervising public audits in Brazil play complementary and integrated roles. The Federal Court of Accounts (TCU) acts as the external control body of federal administration, monitoring the application of Union resources and advising the National Congress. The Office of the Comptroller General (CGU), in turn, is the central body of the internal control system of the Federal Executive Branch, responsible for conducting preventive audits, investigating irregularities, and promoting transparency and citizen engagement (CGU, 2020). At the state and municipal levels, Courts of Accounts and Comptroller's Offices perform similar functions, overseeing the application of regional and local resources, reinforcing the decentralized and cooperative nature of Brazil's control system (Silva; Rezende, 2020).

Public auditing activities are supported by a robust normative framework. The International Standards of Supreme Audit Institutions (ISSAIs), issued by INTOSAI, constitute the main theoretical and technical reference for governmental auditing globally. Among them, ISSAI 100 establishes the fundamental principles of public sector auditing, and ISSAI 3000 addresses performance audits (INTOSAI, 2019).

In Brazil, these guidelines are complemented by the Brazilian Accounting Standards Applied to Auditing (NBC TAs), issued by the Federal Accounting Council (CFC), and by audit manuals prepared by oversight bodies, such as the Operational Audit Manual and the Technical Reference for Internal Governmental Audit Activity of the Federal Executive Branch, published by TCU and CGU, respectively.

These normative and technical instruments ensure the standardization of procedures and the alignment of national practices with international best practices, strengthening audit credibility and expanding transparency in public management. As Figueiredo and Santos (2018) emphasize, compliance with professional standards ensures that audits are conducted independently, objectively, and based on evidence, allowing their results to serve as a reliable basis for decision-making and accountability to society.

Thus, the structure and types of auditing in the public sector form an integrated control system that encompasses everything from verifying legal compliance to evaluating results and performance. When well-coordinated, this system decisively contributes to strengthening governance, integrity, and administrative efficiency, promoting public management oriented toward transparency, responsibility, and continuous improvement.

CONTROL IN PUBLIC MANAGEMENT: CONCEPTUAL AND LEGAL ASPECTS

Control in public management constitutes one of the fundamental pillars of democratic administration, representing the set of mechanisms through which legality, legitimacy, morality, and efficiency of acts performed by public administration are ensured. Historically, control emerged as an intrinsic necessity of State management, with the purpose of guaranteeing that public resources are used appropriately and in compliance with constitutional principles of administration (Brazil, 1988).

According to Meirelles (2016), administrative control is the faculty available to the administration to monitor its own acts and those of its agents, correcting possible irregularities and ensuring compliance with the public interest. This internal control is exercised within the governmental structure itself and aims to prevent failures, guarantee legality, and promote administrative efficiency. Social control, according to Secchi (2017), is the power granted to civil society to oversee State actions, constituting an instrument of citizenship and democratic participation. Through it, citizens—directly or through representative institutions—can monitor the implementation of public policies, demand transparency, and require accountability from managers.

The types of control in public administration can be classified as internal, external, and social, each with its own nature, scope, and instruments. Internal control is exercised by bodies and units that are part of the administration itself and aims to ensure regularity in management and proper application of public resources. According to Article 74 of the Federal Constitution of 1988, internal control systems must support external control in fulfilling its institutional mission and prevent irregularities in budgetary and financial execution (Brazil, 1988). The Office of the Comptroller General (CGU) is the main body responsible for this type of control at the federal level, performing functions of auditing, correction, ombudsman services, and transparency (CGU, 2020).

External control, in turn, is exercised by bodies independent of the controlled administration, constitutionally assigned to the Legislative branch, with the assistance of Courts of Accounts, to oversee the budgetary and financial execution of public entities. The Federal Court of Accounts (TCU) and State and Municipal Courts of Accounts have the authority to analyze annual accounts of administrators and others responsible for public funds, assets, and values, as well as to conduct audits and inspections to verify compliance and efficiency in management (TCU, 2021). Complementarily, social control acts as a mechanism of oversight exercised directly by civil society, institutionalized through public policy councils, transparency portals, public hearings, and instruments of popular participation provided by law (Rezende; Slomski, 2019).

The legal basis for public control in Brazil is broad and consolidated, establishing normative parameters for the exercise of oversight and administrative responsibility. The Federal Constitution of 1988 is the fundamental milestone, defining in Article 37 the principles of public administration—

legality, impersonality, morality, publicity, and efficiency—and establishing in Article 70 that "accounting, financial, budgetary, operational, and patrimonial oversight" shall be exercised by the Legislative, Executive, and Judiciary branches, with the assistance of Courts of Accounts (Brazil, 1988).

Complementary Law No. 101/2000, known as the Fiscal Responsibility Law (FRL), reinforces these mechanisms by instituting public finance rules aimed at responsibility in fiscal management, requiring transparency and balance between revenues and expenditures. It introduces the principle of managerial responsibility, which imposes fiscal limits and targets on managers and provides sanctions in case of noncompliance (Brazil, 2000). Law No. 14.133/2021, the new Public Procurement and Administrative Contracts Law, consolidated control and governance as central principles, mandating the implementation of integrity mechanisms, risk management, and auditing in procurement processes (Brazil, 2021). Other laws, such as Law No. 12.527/2011 (Access to Information Law) and Law No. 13.303/2016 (State-Owned Enterprises Law), expanded oversight and transparency tools, consolidating control as an essential dimension of modern public management.

In this context, control is directly linked to the concepts of accountability and transparency, which constitute the main pillars of good governance. The term accountability, according to Pinho and Sacramento (2009), refers to the obligation of public managers to account for their acts and decisions, responding for their results to society and oversight institutions. Transparency, in turn, is understood as the clear and accessible provision of information about governmental actions, enabling citizen monitoring and participation. For the International Organization of Supreme Audit Institutions (INTOSAI, 2019), transparency is an indispensable condition for public trust, while accountability ensures the legitimacy of management.

The relationship between control, efficiency, and public responsibility is interdependent. When exercised technically and ethically, control does not constitute an obstacle to administration but rather an instrument for continuous improvement. According to Chiavenato (2014), administrative efficiency is linked to the ability of institutions to learn from the results of their controls, correcting failures and improving processes. Thus, public control should be understood not only as a mechanism of oversight but also as a strategic management process aimed at improving governance and service delivery to society.

Therefore, control in public management goes beyond a merely supervisory role and assumes an educational, guiding, and participatory function. It represents the link between the State's duty to act and the citizen's right to good administration, consolidating itself as an essential instrument for strengthening democracy, efficiency, and integrity in Brazilian public administration.

FROM OVERSIGHT TO IMPROVEMENT: AUDITING AS AN INSTRUMENT OF CONTINUOUS IMPROVEMENT

Public auditing has undergone a paradigmatic transformation in recent decades. Traditionally associated with the function of oversight and detection of irregularities, auditing in contemporary public administration assumes a more strategic posture, oriented toward the continuous improvement of processes and management outcomes. This change stems from the consolidation of an administrative culture based on governance, transparency, and efficiency, in which control ceases to be merely punitive and becomes preventive, educational, and results-oriented (Santos; Almeida, 2019).

The paradigm shift in governmental auditing is linked to the transition from the bureaucratic model to the managerial model of public administration, proposed during the State Reform of the 1990s. According to Bresser-Pereira (1998), this new model sought to overcome the rigidity of formal control, emphasizing efficiency, accountability, and the quality of public services. Thus, auditing began to play a supportive role in management, providing relevant information for planning, decision-making, and the improvement of public policies (Matias-Pereira, 2010).

In this context, operational auditing emerges as an essential tool for evaluating and improving public management. Unlike traditional compliance audits, which focus on legality and correctness of administrative acts, operational auditing aims to examine the economy, efficiency, effectiveness, and impact of governmental actions (TCU, 2020). This modality seeks not only to identify shortcomings but also to propose solutions and best practices that contribute to the continuous improvement of public administration (Cavalcante; Marinho, 2018).

Beyond performance evaluation, operational auditing has been widely used as a risk management instrument. According to the Office of the Comptroller General (CGU, 2022), applying methodologies based on risk identification, analysis, and mitigation allows anticipating problems and reducing waste, making public management more predictable and sustainable. In this way, auditing ceases to act only after failures occur and becomes integrated into the management cycle, contributing to preventive actions and continuous improvement (Rezende, 2019).

Another important aspect is the integration of auditing with quality management systems and public governance. Alignment with standards such as ISO 9001:2015 and with corporate governance principles adapted to the public sector (OECD, 2015) reinforces the need for auditable, transparent, and results-oriented processes. This integration enables public audits to assume an internal consulting role, supporting managers in implementing more effective policies aligned with institutional strategic objectives (Figueiredo; Caggiano, 2017).

Practical experiences demonstrate the transformative potential of improvement-oriented auditing. The Federal Court of Accounts (TCU), for example, has conducted operational audits in areas such as

health, education, and infrastructure, producing recommendations that resulted in direct improvements in the efficiency of public services (TCU, 2021). Similarly, state and municipal comptroller offices have adopted audit models based on performance indicators, fostering a culture of organizational learning and innovation in public management (Souza; Martins, 2020).

Therefore, contemporary public auditing consolidates itself as an instrument of institutional transformation and improvement. More than a control mechanism, it constitutes a continuous process of learning, guidance, and enhancement, capable of strengthening social trust in public institutions. By adopting a collaborative and preventive posture, auditing contributes to the development of a more ethical, efficient administration committed to delivering public value to society (Chiavenato, 2021; Motta, 2013).

CONTEMPORARY CHALLENGES OF AUDITING IN PUBLIC MANAGEMENT

Auditing in Brazilian public management faces a set of challenges that reflect the social, technological, and institutional transformations of the 21st century. Although it has advanced significantly toward becoming more strategic, results-oriented, and a promoter of continuous improvement, its effectiveness is still constrained by structural, technical, and human limitations, as well as cultural and political barriers that hinder its full integration with governance and efficiency principles (Matias-Pereira, 2010; Rezende, 2019).

One of the main obstacles faced by public auditing concerns the structural and technical limitations of oversight bodies. In many cases, audit units suffer from a shortage of financial resources, technological obsolescence, and a lack of specialized personnel, which compromises the execution of complex tasks and the implementation of modern methodologies (Cavalcante; Marinho, 2018). According to the Federal Court of Accounts (TCU, 2021), the overload of demands and the lack of integration between internal and external control systems also result in rework and operational inefficiency, reducing auditing's potential as a governance instrument.

In addition to technical limitations, there are institutional resistances and cultural barriers that hinder innovation. Many public agencies still view auditing through a punitive lens, associating it with a mechanism of oversight and correction rather than an instrument of improvement and learning (Santos; Almeida, 2019). This negative perception, rooted in traditional bureaucratic culture, tends to generate resistance among managers to implementing recommendations presented by auditors, which compromises the effectiveness of corrective and preventive actions (Motta, 2013). Overcoming this obstacle requires a continuous process of cultural and educational change that reinforces the importance of auditing as a management tool and not merely as a control mechanism.

Another significant challenge lies in the integration between internal and external control systems. Although both share the objective of ensuring proper application of public resources and administrative efficiency, in practice, there is still fragmentation of competencies and lack of institutional coordination (CGU, 2022). This lack of articulation results in overlapping audits, divergence of criteria, and communication difficulties among different oversight bodies—such as the Office of the Comptroller General (CGU), Courts of Accounts, and state and municipal comptroller offices. According to Figueiredo and Caggiano (2017), effective public auditing requires inter-institutional cooperation, standardization of methods, and information sharing to promote synergy and avoid redundancies.

The technological revolution constitutes both an opportunity and a challenge for contemporary public auditing. The use of Big Data tools, Artificial Intelligence, and predictive analytics has the potential to profoundly transform how public management control is carried out. Digital auditing enables continuous monitoring of large volumes of data, identifying anomalies, risk patterns, and signs of irregularities in real time (OECD, 2021). However, adopting these technologies requires technical training, adequate infrastructure, and an organizational culture oriented toward innovation, which is still limited in many Brazilian institutions (Rezende, 2019; CGU, 2022). Furthermore, new ethical dilemmas arise related to data privacy, algorithmic transparency, and responsible use of technology in public oversight.

Given this context, continuous training and professional ethics stand out as pillars of public auditing modernization. The growing complexity of administration demands auditors with multidisciplinary skills, capable of understanding not only accounting and legal aspects but also managerial, technological, and social dimensions of public policies (Bresser-Pereira, 1998). According to Chiavenato (2021), constant updating is essential to ensure that auditors act with independence, impartiality, technical competence, and ethical commitment—attributes indispensable for the credibility and legitimacy of the control function.

Thus, contemporary public auditing needs to balance intensive use of technology with the strengthening of its human and institutional foundations. Addressing structural, cultural, and technical challenges requires strategic planning, investment in innovation, and reinforcement of professional capabilities. More than correcting failures, auditing should be recognized as an instrument of organizational learning and institutional development, capable of promoting a more efficient, ethical public management oriented toward delivering social value (Souza; Martins, 2020; OECD, 2021).

FUTURE PERSPECTIVES AND TRENDS IN GOVERNMENT AUDITING

Recent transformations in public administration and advances in information technology have elevated government auditing to a new level of performance, shifting its focus from traditional control to

a strategic, predictive approach oriented toward risks and results. In this scenario, public auditing is increasingly understood as an essential instrument of governance, integrity, and administrative innovation, actively contributing to the efficiency and legitimacy of the State before society (Rezende, 2019; OECD, 2021).

One of the most relevant trends in this context is risk-based auditing (RBA). Unlike traditional models that inspect samples or past events, RBA is guided by the identification and prioritization of risks that may compromise organizational objectives, allowing auditors to act preventively and strategically (TCU, 2021). As highlighted by the Office of the Comptroller General (CGU, 2022), this methodology makes the audit process more efficient by directing efforts toward areas of greater vulnerability and impact, thereby optimizing the rational use of public resources. Furthermore, RBA integrates performance indicators and efficiency metrics, enabling the evaluation not only of legal compliance but also of the results and impacts of public policies (Souza; Martins, 2020).

Performance-oriented auditing represents another significant advancement. It is based on the analysis of quantitative and qualitative evidence that demonstrates the effectiveness of governmental actions, assisting managers and decision-makers in understanding whether planned goals are being achieved (Matias-Pereira, 2010). This approach reinforces the logic of results-based evaluation, typical of New Public Management, and allows auditing to act not only as an oversight mechanism but also as a strategic partner in improving management (Cavalcante; Marinho, 2018).

At the same time, auditing plays an increasingly important role in strengthening governance and public integrity. According to OECD (2021), good governance presupposes transparency, accountability, fairness, and responsibility—values that align directly with the mission of government auditing. In this sense, the contemporary auditor acts not only in verifying compliance but also in promoting ethical values, combating corruption, and disseminating sustainable and integrity-based practices (CGU, 2022). Strengthening integrity programs and coordinating audits with internal affairs and ombudsman offices become essential for building an institutional culture of trust and public ethics (Figueiredo; Caggiano, 2017).

Another vector of transformation is the expansion of active transparency and social involvement in audit processes. Contemporary society increasingly demands access to clear, comprehensive, and real-time information on the use of public resources. In this context, oversight bodies have adopted practices such as open data, interactive audit dashboards, and simplified public reports, enabling citizens to monitor oversight activities and actively participate in social control (TCU, 2020; Brazil, 2021). Auditing, therefore, assumes a pedagogical and democratic role, expanding dialogue between the State and civil society and strengthening both horizontal and vertical accountability (Santos; Almeida, 2019).

Finally, future perspectives point to the consolidation of auditing as a strategic agent of modernization and administrative efficiency. The incorporation of technologies such as artificial intelligence, machine learning, predictive analytics, and blockchain promises to revolutionize auditing practices, enabling greater precision, agility, and depth in analyzing public data (OECD, 2021). However, this modernization requires continuous investment in training, technological infrastructure, and professional ethics to ensure that the use of these tools respects principles of legality, transparency, and impartiality (Chiavenato, 2021).

Thus, the future of government auditing is built upon four fundamental pillars: risk-based management, governance and integrity, transparency, and technological innovation. By integrating these elements, auditing ceases to be merely a reactive control mechanism and assumes a proactive and strategic role, oriented toward creating public value and strengthening society's trust in state institutions. As Rezende (2019) summarizes, the challenge is to transform auditing into an instrument of learning and transformation, capable of driving the State toward efficiency, ethics, and excellence in public management.

CONCLUSION

The conclusion of this study highlights the strategic role of auditing in Brazilian public management, consolidating it as an essential instrument for promoting transparency, efficiency, and administrative accountability. Throughout the analysis, it was possible to observe the historical evolution of auditing, which shifted from a merely punitive and control-oriented approach to a more modern and proactive perspective focused on continuous improvement and the efficiency of public services. This transformation reflects a paradigm shift in public administration, where auditing not only monitors but also guides managers, promotes best practices, and contributes to strengthening governance.

The results obtained indicated that, despite significant progress, public auditing still faces challenges that limit its effectiveness. Issues such as lack of resources, cultural resistance in some institutions, and fragmentation between internal and external control systems were identified as obstacles that need to be overcome to ensure that auditing fully fulfills its role. Overcoming these barriers is essential for auditing to act not only in detecting irregularities but also as an agent of transformation, promoting a more ethical public administration committed to delivering value to society.

The analysis of contemporary auditing practices revealed that integrating modern methodologies, such as risk-based auditing and results-oriented approaches,

can enhance the effectiveness of public audits. Adopting these approaches allows auditors to focus their efforts on areas of greater vulnerability and impact, contributing to a more rational use of public resources. Furthermore, the growing demand for transparency and social participation reinforces the need for auditing to become a more collaborative process, involving civil society and promoting effective social control.

Finally, it is crucial that auditing institutions continue to invest in professional training and the incorporation of technological innovations to strengthen their technical and ethical capacities. The future of public auditing in Brazil will depend on its ability to adapt to new challenges and realities, always seeking process improvement and promoting a more efficient and transparent public administration. Thus, this study contributes to a deeper understanding of auditing in public management, emphasizing its essential role in building a State that is more responsible and committed to society's demands.

REFERENCES

1. Brasil. Constituição da República Federativa do Brasil de 1988 [Constitution of the Federative Republic of Brazil of 1988]. Brasília, DF: Senado Federal, 1988.

2. Brasil. Lei Complementar nº 101, de 4 de maio de 2000. Estabelece normas de finanças públicas voltadas para a responsabilidade na gestão fiscal [Complementary Law No. 101 of May 4, 2000: Establishes Public Finance Rules for Fiscal Responsibility]. Diário Oficial da União, Brasília, DF, 2000.

3. Brasil. Lei nº 12.527, de 18 de novembro de 2011. Regula o acesso a informações previsto na Constituição Federal [Law No. 12,527 of November 18, 2011: Regulates Access to Information Provided for in the Federal Constitution]. Diário Oficial da União, Brasília, DF, 2011.

4. Brasil. Lei nº 13.303, de 30 de junho de 2016. Dispõe sobre o estatuto jurídico das empresas estatais [Law No. 13,303 of June 30, 2016: Provides for the Legal Framework of State-Owned Enterprises]. Diário Oficial da União, Brasília, DF, 2016.

5. Brasil. Lei nº 14.133, de 1º de abril de 2021. Institui normas gerais de licitação e contratação para a administração pública [Law No. 14,133 of April 1, 2021: Establishes General Rules on Public Procurement and Contracting]. Diário Oficial da União, Brasília, DF, 2021.

6. Bresser-Pereira, Luiz Carlos. A reforma do Estado nos anos 90: lógica e mecanismos de controle [The State Reform in the 1990s: Logic and Control Mechanisms]. Brasília: ENAP, 1998.

7. Cavalcante, Pedro; Marinho, José. Gestão pública e desempenho organizacional: abordagens e práticas contemporâneas [Public Management and Organizational Performance: Contemporary Approaches and Practices]. Brasília: IPEA, 2018.

8. CFC – Conselho Federal de Contabilidade. Normas Brasileiras de Contabilidade Aplicadas à Auditoria (NBC TAs) [Brazilian Accounting Standards Applied to Auditing (NBC TAs)]. Brasília: CFC, 2016.

9. CGU – Controladoria-Geral da União. Referencial Técnico da Atividade de Auditoria Interna Governamental do Poder Executivo Federal [Technical Reference for Internal Governmental Audit Activities of the Federal Executive Branch]. Brasília: CGU, 2020.

10. Chiavenato, Idalberto. Introdução à teoria geral da administração [Introduction to the General Theory of Administration]. 9th ed. Rio de Janeiro: Elsevier, 2014.

11. Chiavenato, Idalberto. Introdução à teoria geral da administração [Introduction to the General Theory of Administration]. 9th ed. Rio de Janeiro: Elsevier, 2021.

12. Controladoria-Geral da União (CGU). Guia de gestão de riscos e controles internos da administração pública federal [Guide to Risk Management and Internal Controls in the Federal Public Administration]. Brasília: CGU, 2022.

13. Controladoria-Geral da União (CGU). Relatório de gestão de riscos e controle interno [Report on Risk Management and Internal Control]. Brasília: CGU, 2022.

14. Figueiredo, Marcelo A.; Santos, Ricardo P. Auditoria governamental: fundamentos e práticas [Government Auditing: Fundamentals and Practices]. São Paulo: Atlas, 2018.

15. Figueiredo, Sandra; Caggiano, Paulo Cesar. Controladoria: teoria e prática [Controllership: Theory and Practice]. 6th ed. São Paulo: Atlas, 2017.

16. INTOSAI. ISSAI 100 – Princípios Fundamentais da Auditoria do Setor Público [Fundamental Principles of Public Sector Auditing]. Vienna: INTOSAI, 2019.

17. INTOSAI. ISSAI 3000 – Normas de Auditoria de Desempenho [Performance Audit Standards]. Vienna: INTOSAI, 2019.

18. Matias-Pereira, José. Manual de gestão pública contemporânea [Handbook of Contemporary Public Management]. 3rd ed. São Paulo: Atlas, 2010.

19. Meirelles, Hely Lopes. Direito administrativo brasileiro [Brazilian Administrative Law]. 43rd ed. São Paulo: Malheiros, 2016.

20. Motta, Paulo Roberto. Gestão contemporânea: a ciência e a arte de ser dirigente [Contemporary Management: The Science and Art of Leadership]. 4th ed. Rio de Janeiro: Record, 2013.

21. OCDE – Organização para a Cooperação e Desenvolvimento Econômico. Governança pública: princípios e práticas recomendadas [Public Governance: Principles and Best Practices]. Paris: OECD Publishing, 2015.

22. OCDE – Organização para a Cooperação e Desenvolvimento Econômico. Public Audit in the Digital Age: Opportunities and Challenges. Paris: OECD Publishing, 2021.

23. Pinho, José A. G.; Sacramento, Ana R. S. Accountability: já podemos traduzi-la para o português? [Accountability: Can We Translate It into Portuguese Yet?] Revista de Administração Pública, Rio de Janeiro, v. 43, n. 6, p. 1343–1368, 2009.

24. Rezende, Denis A.; Slomski, Valmor. Gestão pública: controle, transparência e governança [Public Management: Control, Transparency, and Governance]. Curitiba: Juruá, 2019.

25. Rezende, Denis Alcides. Planejamento estratégico público e governança: conceitos, metodologias e práticas [Public Strategic Planning and Governance: Concepts, Methodologies, and Practices]. 2nd ed. Rio de Janeiro: Elsevier, 2019.

26. Santos, Maria Aparecida; Almeida, Cláudio Henrique de. Auditoria governamental e accountability: práticas e desafios [Government Auditing and Accountability: Practices and Challenges]. Revista de Administração Pública, v. 53, n. 2, p. 321–340, 2019.

27. Secchi, Leonardo. Modelos organizacionais e reforma da administração pública [Organizational Models and Public Administration Reform]. 2nd ed. Brasília: ENAP, 2017.

28. Silva, Edson P.; Rezende, Denis A. Gestão pública e controle interno: fundamentos e práticas [Public Management and Internal Control: Fundamentals and Practices]. Curitiba: Juruá, 2020.

29. Souza, Tiago; Martins, Fabiana. Auditoria pública orientada a resultados: inovação e aprendizado na gestão municipal [Results-Oriented Public Auditing: Innovation and Learning in Municipal Management]. Revista do Serviço Público, v. 71, n. 4, p. 655–674, 2020.

30. Tribunal de Contas da União (TCU). Auditoria operacional: manual de referência [Operational Audit: Reference Manual]. Brasília: TCU, 2021.

31. Tribunal de Contas da União (TCU). Manual de Auditoria Operacional [Operational Audit Manual]. Brasília: TCU, 2021.

32. Tribunal de Contas da União (TCU). Relatório de Atividades – Auditoria Operacional [Activity Report – Operational Audit]. Brasília: TCU, 2021.

ISBN: 978-65-83849-24-3

BREASTFEEDING IN THE PREVENTION OF BREAST CANCER

https://doi.org/10.63330/aurumpub.021-004

Rosângela Thomé da Silva[1]

ABSTRACT

This study addressed breastfeeding as a protective factor in the prevention of breast cancer, highlighting the biological, physiological, and epidemiological mechanisms that support this relationship. The main objective was to analyze, in light of scientific literature, how breastfeeding contributes to reducing the risk of developing breast cancer, understanding its hormonal and cellular bases and its impact on public health. The research was bibliographic and qualitative in nature, grounded in national and international studies from organizations such as the World Health Organization (WHO), the National Cancer Institute (INCA), and scientific articles indexed in recognized databases. Evidence reviewed demonstrated that breastfeeding significantly reduces the risk of breast cancer, particularly in women who breastfed for prolonged periods, due to decreased exposure to estrogen, suppression of the ovulatory cycle, and induction of apoptosis and cellular renewal processes in the mammary gland. The investigation also revealed that breast physiology during lactation involves hormonal and structural changes that promote not only milk production but also protective cellular differentiation and tissue balance. Results showed that breastfeeding is essential not only for the healthy development of the child but also as an effective measure for breast cancer prevention, with long-lasting benefits for women's health. It was found that each additional cumulative breastfeeding period represented a percentage reduction in breast cancer risk, reinforcing the dose-response nature of this protection. The study concluded that encouraging and supporting breastfeeding is a low-cost, high-impact public health strategy with the potential to reduce female morbidity and mortality and promote physical, emotional, and social well-being. Thus, the research reaffirmed the importance of integrating public policies aimed at promoting breastfeeding and raising awareness of its preventive benefits for both mothers and society.

Keywords: Breastfeeding; Breast cancer; Prevention; Women's health; Maternal lactation.

[1] Master in Biomedical Engineering - UnB
E-mail: rosangelaengbio@gmail.com

INTRODUCTION

Breastfeeding is a biological, social, and cultural phenomenon that plays a fundamental role in maternal and child health and in the prevention of various diseases throughout life. In addition to ensuring optimal nutrition and healthy development of the newborn, breastfeeding has been widely recognized for its protective effects on women's health, particularly in reducing the risk of developing breast cancer. Contemporary scientific literature, represented by studies from the World Health Organization (WHO, 2020), the National Cancer Institute (INCA, 2023), and authors such as Victora et al. (2016) and Silva et al. (2018), emphasizes that exclusive breastfeeding until six months of age and continued breastfeeding up to two years or beyond is associated not only with improved child health indicators but also with the prevention of chronic and neoplastic diseases in mothers.

Breast cancer, in turn, is the most common malignant neoplasm among women worldwide, representing a major public health problem due to its high mortality rate and psychosocial impact. According to INCA (2023), it is estimated that more than 70,000 new cases are diagnosed annually in Brazil, highlighting the need for effective preventive strategies. In this context, understanding the relationship between breastfeeding and breast cancer prevention is essential for strengthening public health policies and expanding scientific knowledge about the physiological and hormonal mechanisms that explain this association.

The general objective of this study was to analyze scientific evidence linking breastfeeding to reduced breast cancer risk, highlighting the physiological, biological, and epidemiological aspects that support this relationship. Specifically, it sought to understand hormonal and tissue changes occurring in the breast during lactation, identify biological mechanisms of protection conferred by breastfeeding, and discuss study results indicating risk reduction according to breastfeeding duration.

The central hypothesis of this work was based on the premise that breastfeeding exerts a protective effect on breast tissue, as it promotes cellular differentiation, hormonal regulation, and reduced exposure to estrogen—factors recognized for lowering carcinogenic potential. Furthermore, it is assumed that prolonged breastfeeding is associated with cumulative protection, reinforcing its importance as a primary prevention strategy for breast cancer.

The justification for conducting this research lies in the social and scientific relevance of the topic, considering that breastfeeding is a natural, low-cost practice with significant impact on women's health. Promoting breastfeeding, therefore, not only strengthens the mother-child bond but also represents a preventive measure against serious diseases, contributing to reduced female mortality and advancing public health policies.

Methodologically, the study was developed through a qualitative bibliographic review based on the analysis of books, scientific articles, systematic reviews, reports from international organizations,

and official documents from the Ministry of Health and the World Health Organization. Information was selected and organized into thematic axes addressing, respectively, the concept and importance of breastfeeding, general aspects of breast cancer, breast physiology during lactation, biological mechanisms of protection, and scientific evidence on the relationship between breastfeeding and breast cancer prevention.

Ultimately, the research demonstrated that breastfeeding is essential for the comprehensive health of women and children, representing a powerful tool for prevention and health promotion. Thus, the study reaffirmed the importance of encouraging breastfeeding as a public policy and as an individual behavior for protecting life and women's health.

METHODOLOGY

This study was characterized as a bibliographic and qualitative research focused on analyzing scientific evidence linking breastfeeding to breast cancer prevention. The investigation was based on books, scientific articles, reports, and official documents from institutions such as the Ministry of Health, INCA, WHO, and UNICEF, as well as publications available in databases such as SciELO, PubMed, Google Scholar, and LILACS. Priority was given to studies published between 2016 and 2023, complemented by classic references on the subject.

Inclusion criteria encompassed works addressing the benefits of breastfeeding for women's health, physiological and hormonal mechanisms of lactation, and the relationship between breastfeeding and breast cancer. Publications lacking scientific basis were excluded. Material was analyzed through selective reading and critical interpretation, organized into thematic axes corresponding to the sections of the study.

As this was a theoretical study, there was no involvement of human subjects, thus exempting ethical review. This methodology enabled the construction of an integrated and well-founded perspective on the importance of breastfeeding as a natural and effective strategy for promoting women's health and preventing breast cancer.

DEVELOPMENT

CONCEPT AND IMPORTANCE OF BREASTFEEDING

Breastfeeding is a fundamental biological and social process that involves feeding the newborn with breast milk directly from the mother's breast. According to the World Health Organization (WHO, 2020), breastfeeding is the most natural and effective way to ensure nutrition, growth, and healthy development of the child, being recommended exclusively for the first six months of life and, complementarily, up to two years or beyond. This practice transcends the simple act of feeding,

constituting a moment of emotional bonding, security, and interaction between mother and child, essential for the baby's physical and emotional development (BRASIL, 2021).

The definition of breastfeeding, according to UNICEF (2021), encompasses any practice in which breast milk is offered to the child, whether directly at the breast or expressed, emphasizing that exclusive breastfeeding occurs when the child receives only the mother's milk, without other liquids or foods. Breast milk is a complete food, containing proteins, fats, vitamins, minerals, and antibodies in ideal proportions to meet the baby's needs (SILVA et al., 2018). Furthermore, it has immunological and anti-inflammatory properties that protect the child against respiratory infections, diarrhea, allergies, and various chronic non-communicable diseases (VICTORA et al., 2016).

The benefits of breastfeeding are not limited to the baby. For the mother, breastfeeding contributes to postpartum uterine recovery, reduces the risk of hemorrhage, and favors a faster return to pre-pregnancy weight (BRASIL, 2021). Studies also indicate that the practice is associated with a lower incidence of breast and ovarian cancer, as well as a reduced risk of developing type 2 diabetes and cardiovascular diseases (VICTORA et al., 2016; LIMA; GOMES, 2020). For the baby, benefits include better cognitive and emotional development, strengthening of the immune system, and reduced infant mortality (WHO, 2020).

From a social and economic perspective, breastfeeding also brings significant benefits. By reducing the need for artificial formulas and hospitalizations for preventable diseases, it contributes to saving public and private health resources (ROLLINS et al., 2016). Thus, breastfeeding is an investment in health and sustainable human development, positively impacting indicators of mortality, nutrition, and quality of life (SILVA et al., 2018).

The relevance of breastfeeding for public health is widely recognized. The Ministry of Health (BRASIL, 2021) considers breastfeeding one of the pillars of child health promotion policies due to its potential to prevent diseases and strengthen family bonds. The practice is regarded as a low-cost, high-impact intervention capable of significantly reducing neonatal and infant mortality. WHO (2020) estimates that increasing exclusive breastfeeding rates up to six months could save more than 800,000 infant lives annually worldwide.

In this sense, encouraging and protecting breastfeeding is a collective responsibility involving effective public policies, adequate professional support, and social awareness. Campaigns and programs aimed at promoting breastfeeding, such as the Baby-Friendly Hospital Initiative (BFHI), have proven effective in increasing breastfeeding rates and creating supportive environments for mothers (UNICEF, 2021). Thus, breastfeeding is not merely an individual act but a social and public health practice that directly reflects on population well-being and the construction of a healthier and more supportive society.

BREAST CANCER: GENERAL ASPECTS

Breast cancer is one of the most studied and discussed diseases in public health due to its high incidence and social and emotional impact on women's lives. According to the National Cancer Institute (INCA, 2023), breast cancer is characterized by the uncontrolled multiplication of abnormal cells in the breast, forming a tumor with the potential to invade adjacent tissues and spread to other parts of the body (metastasis). It is the most common type of cancer among women worldwide and the leading cause of cancer-related death in this population, representing a major challenge for health systems (WHO, 2022).

There are several types of breast cancer, classified according to their cellular origin and clinical behavior. The most frequent are ductal and lobular carcinomas, originating respectively in the lactiferous ducts and mammary lobules (BRASIL, 2023). Invasive ductal carcinoma accounts for about 80% of cases and is known for its ability to invade surrounding breast tissue and eventually reach other organs (SOUZA; PEREIRA, 2021). Invasive lobular carcinoma is less common but tends to present multiple foci in the breast and sometimes in both breasts. Additionally, there are in situ carcinomas, considered precursor lesions that have not yet invaded neighboring tissues and can be detected early through screening exams such as mammography (INCA, 2023).

Risk factors for breast cancer are varied and include genetic, hormonal, behavioral, and environmental components. Among genetic factors, mutations in the BRCA1 and BRCA2 genes stand out, conferring a higher predisposition to the disease and often associated with familial cases (THOMAS; WATSON, 2020). In the hormonal field, prolonged exposure to estrogen—whether due to early menarche, late menopause, nulliparity, or long-term use of hormonal therapies—increases the risk of tumor development (SILVA; LOPES, 2019). From an environmental and behavioral perspective, factors such as physical inactivity, excessive alcohol consumption, obesity, smoking, and diets rich in saturated fats have been widely associated with the disease (WHO, 2022).

Other important aspects include aging, as breast cancer risk increases with age, and exposure to ionizing radiation, especially in women who underwent chest radiotherapy at a young age (BRASIL, 2023). Although some risk factors are non-modifiable, such as genetic inheritance, many are related to lifestyle and can be prevented through health promotion actions, preventive education, and early screening (SOUZA; PEREIRA, 2021).

The incidence of breast cancer has been rising in recent decades, particularly in developing countries, due to urbanization, lifestyle changes, and increased life expectancy. According to WHO (2022), more than 2.3 million new cases are diagnosed annually worldwide, representing about 11.7% of all new cancer cases. In Brazil, INCA (2023) projects more than 70,000 new cases per year for the 2023–2025 period, with an estimated risk of 66.5 cases per 100,000 women.

The impact of breast cancer on the female population is profound and multifaceted. In addition to physical and psychological repercussions, the diagnosis significantly affects women's social, professional, and family lives. Treatment may involve surgery, radiotherapy, chemotherapy, and hormone therapy—procedures that require emotional support and multidisciplinary follow-up (SILVA; LOPES, 2019). Coping with the disease is also related to self-esteem and female identity, as the breast holds symbolic value linked to motherhood and femininity (THOMAS; WATSON, 2020).

From a public health perspective, breast cancer represents a major global problem. Early detection and expanded access to preventive exams, such as mammography, are fundamental strategies to reduce mortality and improve prognosis (BRASIL, 2023). Programs such as Pink October have played a relevant role in raising awareness and encouraging regular exams, as well as promoting debate on the importance of early diagnosis and appropriate treatment. Thus, understanding the general aspects of breast cancer is essential for formulating effective public policies and strengthening comprehensive women's health care.

BREAST PHYSIOLOGY DURING LACTATION

The physiology of the breast during lactation is a complex and dynamic process involving a series of hormonal, cellular, and tissue changes coordinated to enable the production and ejection of breast milk. From the onset of pregnancy to the post-weaning period, the breast undergoes profound structural and functional modifications that ensure not only the newborn's nutrition but also play a protective role in women's health (NEVES; ALMEIDA, 2020). Lactation is, therefore, a fundamental physiological phenomenon resulting from the integration between the endocrine system and mammary tissue, under the direct influence of hormones such as prolactin, oxytocin, estrogen, and progesterone (GUERRA; FREITAS, 2019).

During pregnancy and lactation, the woman's body experiences significant hormonal changes. Prolactin, produced by the anterior pituitary gland, is the main hormone responsible for milk synthesis and secretion. Its release increases significantly after childbirth, when estrogen and progesterone levels drop—hormones that, during pregnancy, inhibit prolactin's action on mammary alveoli (SILVA et al., 2018). Oxytocin, secreted by the neurohypophysis, promotes the contraction of myoepithelial cells surrounding the alveoli and mammary ducts, enabling milk ejection, a phenomenon known as the "let-down reflex" (BRASIL, 2021). Additionally, hormones such as cortisol, insulin, and growth hormone also participate in regulating lactogenesis, ensuring the metabolic balance necessary for adequate milk production (GUERRA; FREITAS, 2019).

Cellular and tissue modifications occurring in the breast during and after breastfeeding are equally significant. During pregnancy, under hormonal influence, there is intense proliferation of

lactiferous ducts and differentiation of secretory alveoli, which become the main functional component of the mammary gland (NEVES; ALMEIDA, 2020). At the onset of lactation, alveolar epithelial cells specialize in synthesizing milk components such as proteins, lipids, and lactose. This process is accompanied by increased vascularization and lymphatic flow, ensuring the supply of nutrients necessary for milk secretion (SILVA et al., 2018).

After breastfeeding ends, mammary involution occurs, characterized by apoptosis (programmed cell death) of secretory epithelial cells and reabsorption of milk components, leading to partial regression of alveolar structures (BRASIL, 2021). This process is mediated by hormonal and immunological signals that restore mammary tissue to its pre-pregnancy state, although studies indicate that some cellular modifications persist, conferring long-term protective effects against neoplasia development (GONÇALVES; SANTOS, 2022).

The cellular differentiation process occurring during breastfeeding plays a fundamental role not only in secretory function but also in breast protection. Complete maturation of mammary epithelial cells induced by lactation promotes the expression of genes related to genomic stability and mutation suppression, reducing the risk of malignant transformation (THOMAS; WATSON, 2020). Furthermore, controlled apoptosis of cells after weaning prevents the accumulation of damaged cells, contributing to tissue renewal and maintenance of gland integrity (GONÇALVES; SANTOS, 2022). Research suggests that women who breastfeed for prolonged periods have a lower incidence of breast cancer, precisely due to the protective effect associated with differentiation and efficient cell elimination (VICTORA et al., 2016).

Thus, breast physiology during lactation reveals the complex interaction between the endocrine system, mammary tissue, and maternal metabolism. Lactation is not limited to milk production but represents an integrated physiological process that provides simultaneous benefits to mother and child. Hormonal balance, cellular adaptations, and the protective role of tissue differentiation reinforce the importance of breastfeeding as a biological function essential to health and disease prevention (NEVES; ALMEIDA, 2020; BRASIL, 2021).

BIOLOGICAL MECHANISMS OF PROTECTION CONFERRED BY BREASTFEEDING

The biological mechanisms that explain the protection conferred by breastfeeding to female breast health are related to a set of hormonal, cellular, and metabolic processes that reduce the breast's exposure to proliferative stimuli and promote a physiological environment of lower risk for neoplasia development. Several studies indicate that breastfeeding plays a significant protective role against breast cancer, mainly by modulating hormonal activity, inducing cellular differentiation of mammary glands,

and reducing cumulative exposure to estrogen throughout a woman's reproductive life (VICTORA et al., 2016; THOMAS; WATSON, 2020).

One of the central mechanisms of this protection is the reduction of exposure to female hormones, especially estrogen. During breastfeeding, lactation suppresses ovulation through inhibition of the hypothalamic-pituitary-ovarian axis, resulting in low circulating levels of gonadotropins and, consequently, estrogen (GUERRA; FREITAS, 2019). When present in high concentrations for prolonged periods, this hormone stimulates the proliferation of mammary epithelial cells, increasing the risk of mutations and malignant transformation (SILVA; LOPES, 2019). Thus, by reducing estrogen exposure, breastfeeding limits the number of menstrual cycles and, therefore, the total time of hormonal influence on breast tissue (WHO, 2022).

In addition to hormonal modulation, breastfeeding profoundly influences apoptosis and cellular renewal mechanisms in the breast. During lactation, alveolar epithelial cells are highly differentiated and metabolically active, dedicated to milk production and secretion. After weaning, a physiological involution process occurs, characterized by apoptosis of secretory cells and reabsorption of milk components (GONÇALVES; SANTOS, 2022). This programmed cell death process is essential because it eliminates potentially damaged cells or those with genetic alterations accumulated during the lactation cycle. Furthermore, involution stimulates mammary tissue remodeling, restoring its structure and functionality, which contributes to maintaining tissue homeostasis and reducing the risk of neoplastic transformation (NEVES; ALMEIDA, 2020).

Controlled cellular renewal during and after lactation also promotes efficient regeneration of mammary epithelium. This mechanism is associated with the activation of genetic pathways related to tumor suppression and DNA stability, conferring greater resistance to mutagenic processes (THOMAS; WATSON, 2020). Thus, breastfeeding not only exerts an immediate protective effect but also induces lasting epigenetic modifications that keep mammary tissue in a state less susceptible to carcinogenesis.

Another relevant aspect is the reduction in the number of ovulatory cycles, which directly impacts the decreased risk of breast cancer. Women who breastfeed for prolonged periods experience long intervals of lactational amenorrhea, during which ovarian hormone production is naturally suppressed (VICTORA et al., 2016). This phenomenon reduces cumulative exposure of mammary tissue to estrogen and progesterone—hormones with mitogenic effects—thereby lowering the probability of genetic events responsible for tumor initiation (SILVA; LOPES, 2019). Population studies show that each 12 months of breastfeeding reduces breast cancer risk by approximately 4.3%, regardless of parity or age (WHO, 2022).

Additionally, breastfeeding promotes a distinct metabolic state characterized by mobilization of lipid reserves accumulated during pregnancy and reduction of insulin levels and growth factors such as

IGF-1 (Insulin-like Growth Factor 1), which are associated with cell proliferation and carcinogenesis (GUERRA; FREITAS, 2019). Thus, breastfeeding also contributes to metabolic and hormonal balance, reinforcing the set of biological mechanisms that decrease susceptibility to breast cancer.

In summary, the protection conferred by breastfeeding results from the integration of hormonal, cellular, and metabolic factors that collectively reduce breast tissue exposure to proliferative stimuli, promote the elimination of potentially mutated cells, and stabilize the tissue environment. Therefore, breastfeeding should be recognized not only as a practice of infant nutrition but also as a natural and effective prevention strategy against breast cancer, with long-lasting benefits for women's health (VICTORA et al., 2016; GONÇALVES; SANTOS, 2022).

CONCLUSION

This study concluded that breastfeeding is an essential process not only for the healthy development of the baby but also for the promotion and preservation of women's health, acting as an important protective factor against breast cancer. The analysis of scientific and physiological evidence demonstrated that breastfeeding significantly influences the reduction of breast neoplasia risk due to the interaction of hormonal, cellular, and metabolic mechanisms that promote tissue balance and reduce breast tissue exposure to proliferative stimuli.

It was found that prolonged breastfeeding reduces women's exposure to estrogen—a hormone directly associated with cellular proliferation and breast carcinogenesis. Furthermore, breastfeeding induces cellular differentiation of mammary glands and favors apoptosis and tissue renewal processes, eliminating potentially mutated cells and decreasing the chances of malignant transformation. These mechanisms, combined with the reduction in the number of ovulatory cycles during lactation, biologically explain the protective effect observed in various epidemiological studies and meta-analyses.

The analyzed research highlighted a direct relationship between breastfeeding duration and decreased breast cancer risk, confirming a dose-dependent response pattern: the longer the breastfeeding period, the greater the protection conferred. This finding reinforces the importance of encouraging prolonged breastfeeding for both child well-being and women's health.

The study also emphasized that, beyond its individual benefits, breastfeeding represents an effective public health strategy that is low-cost and high-impact. By preventing diseases and reducing maternal and infant mortality, breastfeeding contributes to the sustainability of health systems and to achieving global health and well-being goals.

Therefore, promoting breastfeeding should be a priority in public health policies, requiring strengthened educational campaigns, institutional support for lactating women, and training of health professionals to provide adequate assistance to mothers. Encouraging breastfeeding is an investment in

prevention, quality of life, and reduction of chronic diseases, consolidating it as a vital practice for women's health and sustainable human development.

Thus, breastfeeding is reaffirmed as an act of love, care, and, above all, protection of life, whose positive effects extend beyond childhood and throughout a woman's life, constituting a powerful ally in the fight against breast cancer.

REFERENCES

1 Brasil. Instituto Nacional de Câncer (INCA). Estimativa 2023: incidência de câncer no Brasil [Estimate 2023: cancer incidence in Brazil]. Rio de Janeiro: INCA, 2023.

2 Brasil. Ministério da Saúde. Guia alimentar para crianças brasileiras menores de 2 anos [Food guide for Brazilian children under 2 years old]. Brasília: Ministério da Saúde, 2021.

3 Gonçalves, A. R.; Santos, M. E. Involução mamária pós-lactação e mecanismos de proteção celular [Post-lactation mammary involution and cellular protection mechanisms]. Revista de Fisiologia e Saúde da Mulher, v. 8, n. 2, p. 45–58, 2022.

4 Guerra, F. J.; Freitas, M. L. Aspectos hormonais e fisiológicos da lactação: uma revisão integrativa [Hormonal and physiological aspects of lactation: an integrative review]. Revista Brasileira de Saúde Materno-Infantil, v. 19, n. 3, p. 595–604, 2019.

5 Lima, A. C.; Gomes, R. F. Aleitamento materno e prevenção de doenças crônicas: revisão integrativa [Breastfeeding and prevention of chronic diseases: an integrative review]. Revista de Saúde Pública, v. 54, n. 22, p. 1–9, 2020.

6 Neves, C. P.; Almeida, D. F. Fisiologia da mama durante a amamentação: alterações hormonais e estruturais [Breast physiology during breastfeeding: hormonal and structural changes]. Revista Médica de Ginecologia e Obstetrícia, v. 28, n. 1, p. 33–42, 2020.

7 Rollins, N. C. et al. Why invest, and what it will take to improve breastfeeding practices? The Lancet, v. 387, n. 10017, p. 491–504, 2016.

8 Silva, M. C. et al. Aleitamento materno: benefícios e desafios na atualidade [Breastfeeding: benefits and current challenges]. Revista Brasileira de Enfermagem, v. 71, n. 4, p. 1974–1981, 2018.

9 Silva, R. L.; Lopes, F. A. Câncer de mama: fatores de risco e estratégias de prevenção [Breast cancer: risk factors and prevention strategies]. Revista Brasileira de Enfermagem Oncológica, v. 5, n. 2, p. 45–56, 2019.

10 Souza, M. T.; Pereira, L. M. Câncer de mama: aspectos clínicos, epidemiológicos e psicossociais [Breast cancer: clinical, epidemiological, and psychosocial aspects]. Revista Saúde em Foco, v. 11, p. 120–135, 2021.

11 Thomas, E. R.; Watson, J. E. Genetic predisposition and hormonal influence in breast cancer development. Journal of Oncology Research, v. 14, n. 3, p. 210–225, 2020.

12 Unicef. Amamentação: um investimento para a vida [Breastfeeding: an investment for life]. Brasília: Fundo das Nações Unidas para a Infância, 2021.

13 Victora, C. G. et al. Breastfeeding in the 21st century: epidemiology, mechanisms, and lifelong effect. The Lancet, v. 387, n. 10017, p. 475–490, 2016.

14 World Health Organization (WHO). Global breast cancer initiative: implementation framework. Geneva: WHO, 2022.

15 World Health Organization (WHO). Infant and young child feeding: model chapter for textbooks for medical students and allied health professionals. Geneva: WHO, 2020.

ISBN: 978-65-83849-24-3

USE OF ARTIFICIAL INTELLIGENCE FOR PROACTIVE DETECTION OF CYBER THREATS IN CORPORATE ENVIRONMENTS

https://doi.org/10.63330/aurumpub.021-005

David Aguiar[1]

ABSTRACT

This study addresses the use of Artificial Intelligence for proactive detection of cyber threats in corporate environments, presenting the main concepts, technologies, and models that enable understanding how the adoption of intelligent solutions strengthens organizations' digital security. The objective was to analyze how techniques such as machine learning, deep learning, behavioral analysis, and event correlation contribute to improving attack identification, especially those lacking known signatures or prior evidence, such as zero-day attacks. The research employed a bibliographic and qualitative methodology, based on the analysis of books, scientific articles, and specialized documents that discuss the evolution of digital threats, the fundamentals of information security, and the role of intelligent technologies in protecting corporate infrastructures. The results demonstrated that traditional security systems exhibit significant limitations in the face of increasingly sophisticated attacks, highlighting the need for tools capable of continuous learning and real-time analysis of large data volumes. It was observed that AI-based solutions allow greater accuracy in anomaly detection, reduction of false positives, anticipation of malicious behaviors, and increased efficiency in incident response. The study concludes that the use of Artificial Intelligence in cybersecurity represents a significant advancement for companies, offering more dynamic, adaptable, and effective resources to combat contemporary threats. Furthermore, the adoption of these technologies contributes to building a safer, more predictable, and resilient organizational environment, reinforcing the importance of investing in intelligent protection models as an essential component of security management strategies.

Keywords: Artificial Intelligence; Cybersecurity; Threat detection; Behavioral analysis; Machine learning.

[1] Executive MBA Course in Cybersecurity

INTRODUCTION

The growing digitalization of corporate processes and the continuous expansion of technological infrastructures have transformed information security into a strategic area for organizations across all sectors. In a scenario where cyberattacks are becoming increasingly sophisticated, fast, and difficult to predict, traditional defense models are no longer sufficient to ensure comprehensive protection of organizational assets.

Thus, the topic Use of Artificial Intelligence for Proactive Detection of Cyber Threats in Corporate Environments gains academic and practical relevance, particularly because it discusses solutions capable of anticipating risks and strengthening companies' digital resilience. Recent literature, including authors such as Stallings (2019), Anderson and Moore (2016), Russell and Norvig (2021), and Goodfellow, Bengio, and Courville (2016), demonstrates that signature-based or rule-based methods are losing ground to intelligent approaches based on continuous learning, behavioral analysis, and anomaly detection.

In this context, it becomes necessary to study how Artificial Intelligence (AI)—especially through techniques such as Machine Learning, Deep Learning, and behavioral analysis—can contribute to proactive threat detection, anticipating suspicious behaviors before they cause significant damage. The central hypothesis of this work is: the use of AI-based intelligent systems significantly increases organizations' ability to identify, predict, and mitigate cyber risks, overcoming the limitations of traditional protection methods. This hypothesis aligns with studies demonstrating AI's potential to identify zero-day attacks (ALMIANI et al., 2020), reduce false positives (KIM; PARK, 2022), correlate large-scale events (GARCIA-TEODORO et al., 2021), and automate traffic and behavioral pattern analysis (SINGH et al., 2019).

The general objective of this article is to analyze the application of Artificial Intelligence in proactive detection of cyber threats in corporate environments, highlighting its benefits, limitations, and impacts on organizational security. Specific objectives include: understanding the fundamentals of information security; presenting the main AI models applied to cybersecurity; discussing intelligent threat detection systems such as IDS/IPS, UEBA, and AI-enhanced SIEM; and examining predictive analysis mechanisms associated with zero-day attack detection and event correlation.

The justification for this study is directly linked to the urgent need for companies to strengthen their digital defense systems in an environment where the volume and complexity of threats grow exponentially. Additionally, understanding how advanced technologies can be integrated into corporate infrastructure is essential for guiding strategic decisions, mitigating risks, and ensuring business continuity. From an academic perspective, this work contributes to the development of the cybersecurity field by consolidating recent research and highlighting emerging trends.

Methodologically, this study was structured as a bibliographic and qualitative research, based on classical authors and contemporary studies in information security and Artificial Intelligence. The methodology includes analysis of scientific articles, books, market reports, and technical documents exploring threat evolution, AI fundamentals applied to security, and advanced detection and response solutions. The structure of the work comprises, in addition to this introduction, a theoretical section divided into four parts: (1) information security in corporate environments; (2) AI and Machine Learning applied to cybersecurity; (3) intelligent threat detection systems; and (4) proactive detection mechanisms. Finally, a conclusion synthesizes the findings and points out future perspectives.

Thus, this introduction provides an overview of the topic, establishes the research scope, and demonstrates its importance in the contemporary context, preparing the reader to understand in an integrated manner the evolution of digital security and the transformative role of Artificial Intelligence in this process.

METHODOLOGY

The methodology adopted in this study is characterized as **bliographic, exploratory, and qualitative research**, grounded in the analysis of books, scientific articles, technical reports, and reference documents addressing information security, artificial intelligence, and advanced methodologies for detecting cyber threats. This approach was chosen due to the need to comprehensively and systematically understand the state of the art regarding the use of Artificial Intelligence in protecting corporate environments, as well as to identify consolidated theoretical and technological contributions in the literature.

The initial stage of the research consisted of defining the central thematic axes guiding the construction of the theoretical framework: (1) fundamentals of information security and its contemporary challenges; (2) concepts and applications of Artificial Intelligence, Machine Learning, and Deep Learning in cybersecurity; (3) intelligent threat detection systems such as AI-based IDS/IPS, UEBA, and SIEM; (4) proactive detection mechanisms, including predictive analysis, event correlation, and zero-day attack identification.

After this delimitation, the selection and analysis of scientific materials published by recognized authors in the field were carried out, such as Stallings (2019), Russell and Norvig (2021), Goodfellow, Bengio, and Courville (2016), Anderson and Moore (2016), in addition to recent studies addressing the evolution of digital threats and AI's role in risk mitigation, such as works by Shone et al. (2018), Moustafa and Slay (2019), Almiani et al. (2020), Garcia-Teodoro et al. (2021), among others. Research was conducted in academic databases such as IEEE Xplore, ACM Digital Library, Google Scholar, and specialized cybersecurity journals.

The analysis of selected materials was conducted through a qualitative approach, prioritizing interpretation, comparison, and synthesis of theoretical contributions. This process allowed identifying trends, gaps, limitations, and advances related to the use of Artificial Intelligence in proactive threat detection, as well as understanding how these technologies transform the corporate security landscape. The exploratory nature of the research enabled broadening comprehension of the topic and highlighting potentialities and challenges associated with adopting intelligent systems.

Additionally, the methodology included an organization and categorization stage, in which content was distributed into thematic sections for the development of the work. This structuring facilitated the construction of a coherent and integrated text, where concepts are progressively related, allowing the reader to understand both fundamentals and practical applications and emerging trends.

Finally, it is noteworthy that the research presents limitations inherent to its bibliographic nature and the rapid evolution of security technologies. However, by consolidating contemporary and classical studies, the adopted methodology provides a current, critical, and in-depth view of the use of Artificial Intelligence in proactive detection of cyber threats and its implications for corporate environments.

DEVELOPMENT

INFORMATION SECURITY IN CORPORATE ENVIRONMENTS

Information security in corporate environments has become one of the essential pillars for business continuity, especially in a scenario where organizations deal daily with large volumes of sensitive data, complex digital interactions, and a significant increase in cyberattacks. In this context, understanding the principles that structure the field—confidentiality, integrity, and availability—is indispensable for assessing risks and establishing effective protection strategies. Confidentiality refers to restricted access to information, ensuring that only authorized individuals can view it; integrity guarantees that data does not undergo unauthorized changes and remains faithful to its original state; while availability ensures that systems and information are accessible whenever necessary for organizational activities (STALLINGS, 2019). Together, these three elements, widely known as the "CIA triad," constitute the foundation of any robust security policy.

However, the growing sophistication of digital threats challenges companies' ability to fully maintain these principles. Among the most frequent and dangerous attack vectors are phishing, ransomware, and polymorphic malware. Phishing employs social engineering techniques to deceive users and obtain credentials or sensitive information, exploiting human and emotional vulnerabilities. Ransomware, in turn, encrypts data and demands payment for restoration, potentially paralyzing entire operations—a phenomenon increasingly common in financial institutions, hospitals, and public services (FERNANDES; OLIVEIRA, 2021). Polymorphic malware represents a significant evolution of

traditional threats by continuously altering its code to evade detection by signature-based antivirus systems, making it particularly difficult to identify and mitigate (SOUZA; MENDES, 2020).

Faced with this challenging scenario, conventional defense models, although still relevant, reveal important limitations. Traditional solutions such as static firewalls, signature-based antivirus, and intrusion detection systems structured on fixed rules are effective against known threats but insufficient against advanced, mutable, and targeted attacks. This occurs because these technologies operate reactively, depending on prior recognition of a malicious pattern to act, leaving a wide margin for zero-day attacks or innovative methods to go unnoticed (ANDERSON; MOORE, 2016). Furthermore, the growing complexity of corporate environments—marked by mobile devices, cloud computing, Internet of Things (IoT), and remote access—increases the attack surface and renders security approaches based exclusively on traditional perimeters obsolete.

Thus, it becomes evident that corporate defense must evolve beyond conventional models, incorporating technologies capable of addressing dynamic and unpredictable threats. The use of artificial intelligence and behavioral analysis has emerged as a promising alternative, enabling proactive anomaly detection and attack anticipation before significant damage occurs. Nevertheless, even with the support of these advanced technologies, the human element continues to play a crucial role, whether as part of the vulnerability or as a key component for a coordinated and strategic response. In short, protecting corporate information today requires a balance between cutting-edge technology, updated security policies, and the development of an organizational culture oriented toward prevention.

ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING APPLIED TO CYBERSECURITY

Artificial Intelligence (AI) and Machine Learning (ML) have become essential elements in strengthening cybersecurity, particularly given the increasing complexity and speed at which new digital threats emerge. At its core, AI refers to the ability of computational systems to perform tasks that would normally require human intelligence, such as pattern recognition, decision-making, and adaptation to new scenarios (RUSSELL; NORVIG, 2021). Machine Learning, in turn, is a subfield of AI focused on developing algorithms capable of learning from data, adjusting their parameters to improve performance over time (MITCHELL, 1997). Within this domain, Deep Learning plays a prominent role, represented by deep neural network architectures that enable the analysis of large volumes of data and extraction of complex patterns—a capability extremely useful for identifying malicious behaviors hidden in large and dynamic network traffic (GOODFELLOW; BENGIO; COURVILLE, 2016).

In cybersecurity, one of the most relevant mechanisms enabled by AI is anomaly detection, a process that consists of identifying unusual behaviors that may indicate ongoing attacks, unauthorized access, or lateral movements within corporate systems. Unlike traditional methods, which rely on

previously known signatures, anomaly detection allows identifying suspicious activities even when there are no prior records of such threats, making it particularly effective against zero-day attacks and sophisticated malware variants (SINGH et al., 2019).

To operationalize these capabilities, different learning models are applied. Supervised algorithms depend on labeled data to learn to distinguish between normal and malicious behaviors, being widely used in classifications such as spam detection, phishing, and cataloged malware. Unsupervised models operate without labels and are particularly useful for detecting hidden patterns and unexpected anomalies, employing techniques such as clustering, autoencoders, and statistical analyses. There are also hybrid approaches that combine characteristics of both models to leverage structured learning and exploratory capacity, resulting in more robust and adaptive systems—especially relevant in large and highly dynamic corporate environments (AHMAD; TRAN; CAMPBELL, 2019).

Recent advances in the field have been widely documented in scientific studies, which show the growing use of AI as a strategic instrument for digital defense. Research by Shone et al. (2018) demonstrates how deep neural networks can outperform traditional techniques in intrusion detection. Buczak and Guven (2016) provide a comprehensive review of ML applications in security, reinforcing the potential of these technologies in mitigating contemporary threats. Collectively, these studies highlight that as attacks become more automated and sophisticated, defense must also rely on intelligent systems capable of learning, anticipating, and acting autonomously.

INTELLIGENT THREAT DETECTION SYSTEMS

The adoption of intelligent threat detection systems has become indispensable in corporate environments given the increasing sophistication and speed of cyberattacks. Among the most relevant solutions in this field are AI-based IDS/IPS, which have evolved significantly compared to traditional models. While conventional systems rely on fixed signatures to identify malicious behaviors, AI-enhanced IDS/IPS use machine learning techniques to analyze traffic patterns, identify anomalies, and detect unknown or highly mutable attacks, such as malware variants and zero-day intrusion attempts (SOMMER; PAXSON, 2010). This adaptive capability reduces dependence on manual updates and increases accuracy, making these systems an essential layer for more autonomous and proactive defense.

Another important innovation is the use of Behavioral Analytics, particularly through the UEBA (User and Entity Behavior Analytics) model. This approach is based on deep analysis of user and entity behavior (such as devices, applications, and service accounts) to identify deviations that may indicate malicious activities, even when there is no signature or known pattern associated with the attack. According to Breadstein and Singh (2019), UEBA can detect anomalous access,

lateral movements, privilege escalation, and internal violations—risks that represent one of the main vulnerabilities of modern companies, as many incidents are caused by employees, compromised credentials, or malicious insiders.

Additionally, SIEM (Security Information and Event Management) systems have been transformed by integrating Artificial Intelligence. Traditionally, SIEM consolidates logs, generates alerts, and provides visibility into security events. However, its large data volume often resulted in overload and prioritization difficulties. With AI, SIEM can automatically correlate events, assign risk levels, predict attacks, and drastically reduce false positives through contextual analyses (GARTNER, 2020). This evolution allows security teams to act more strategically and less reactively, focusing on the most critical incidents.

Finally, the AI-based Zero Trust model represents one of the most promising advances in cybersecurity. Unlike the traditional paradigm, which assumes trust within the network perimeter, Zero Trust assumes that no user, device, or application is trustworthy by default. When combined with AI, this model becomes even more efficient, enabling continuous assessment of behavior and risk for each entity, making dynamic and adaptive access decisions. Studies such as those by Ali and Sharma (2021) show that using intelligent algorithms in Zero Trust reduces the attack surface, prevents unauthorized access in real time, and strengthens distributed corporate architectures, including hybrid and multi-cloud environments.

PROACTIVE THREAT DETECTION

Proactive threat detection has become one of the most advanced pillars of modern cybersecurity, especially in corporate environments where large volumes of data are continuously processed. In contrast to reactive models—which only respond to already identified incidents—the proactive approach seeks to anticipate suspicious behaviors, predict attacks, and act before significant damage occurs. In this context, predictive analysis plays an essential role by using statistical techniques, machine learning, and probabilistic models to identify patterns that typically precede malicious activities. According to Moustafa and Slay (2019), predictive learning-based solutions can analyze network traffic and detect structural anomalies that often precede intrusions or lateral movements, providing security teams with sufficient time to mitigate risks.

Zero-day attack identification is another crucial component of proactive detection. Since these attacks exploit unknown vulnerabilities and therefore lack prior signatures, traditional systems rarely detect them. AI contributes by analyzing atypical behaviors and subtle deviations in process execution, enabling identification of compromise indicators even without historical information. Studies such as those by Almiani et al. (2020) demonstrate that models based on neural networks and deep learning

techniques can achieve significantly higher detection rates than conventional mechanisms, precisely because they do not depend on static lists of known threats.

Another indispensable element is large-scale event correlation, fundamental in complex and distributed environments. Modern security tools collect millions of daily logs from servers, firewalls, applications, endpoints, and clouds. Using AI to correlate this data allows identifying attack chains that, in isolation, would seem harmless. According to Garcia-Teodoro et al. (2021), intelligent correlation systems can reconstruct attack paths, detect coordinated campaigns, and identify anomalies that manifest only on larger scales, such as suspicious simultaneous access, distributed scans, and login attempts spread across different regions.

Finally, reducing false positives through continuous learning represents one of the greatest advances provided by Artificial Intelligence. In traditional solutions, the high rate of incorrect alerts overloads analysts and reduces incident response efficiency. With continuous learning—where models automatically update based on new data—systems can adjust thresholds, recognize normal behaviors specific to each environment, and substantially decrease unnecessary alarms. As highlighted by Kim and Park (2022), techniques such as reinforcement learning and self-adjusting models improve accuracy over time and make detection more contextualized, refined, and aligned with the organization's real dynamics.

CONCLUSION

This study demonstrated that the use of Artificial Intelligence for proactive detection of cyber threats represents one of the most significant advances in the field of information security, particularly in corporate environments operating with complex infrastructures and increasing volumes of data. It was found that digital threats have evolved rapidly, rendering many traditional defense mechanisms—based exclusively on signatures, fixed rules, or manual event analysis—ineffective. In this scenario, intelligent solutions have become essential to enhance organizations' ability to detect, predict, and respond to incidents more quickly and accurately.

Throughout the study, it was possible to understand that supervised, unsupervised, hybrid learning models and advanced deep learning architectures enable the identification of anomalous patterns, correlation of dispersed events, analysis of suspicious behaviors, and anticipation of complex attacks such as zero-day exploits. Furthermore, it was observed that systems such as intelligent IDS/IPS, SIEM platforms integrated with Artificial Intelligence, and UEBA-based solutions reinforce organizations' ability to act preventively, reducing the attack surface and minimizing the occurrence of false positives that traditionally overload security teams.

It was also identified that adopting modern security models, such as Zero Trust combined with AI, strengthens continuous access control, intelligent segmentation, and constant validation of user and

device behavior, allowing companies to operate more securely in distributed, hybrid, and multi-cloud environments.

The results obtained demonstrated that Artificial Intelligence not only increased the efficiency of defense mechanisms but also transformed organizational posture toward digital risks, making it more proactive, adaptive, and resilient. It was concluded that, in addition to improving detection and response processes, AI contributes to a strategic vision of information security, fostering practices of continuous monitoring, contextual analysis, and data-driven decision-making.

Finally, it was noted that despite the advances, challenges remain related to data quality, the need for skilled professionals, and risks inherent to AI models themselves, such as biases and adversarial attacks. However, the benefits far outweigh the limitations, evidencing that Artificial Intelligence has become an indispensable element for strengthening contemporary cybersecurity. Future research should explore more transparent solutions, such as explainable AI, and autonomous incident response models, contributing to the development of increasingly robust defenses integrated into the corporate digital ecosystem.

REFERENCES

1. Ahmad, R.; Tran, D.; Campbell, J. Hybrid Machine Learning Approaches for Detecting Cybersecurity Threats. *Journal of Information Security*, v. 10, n. 3, p. 122–134, 2019.

2. Aliani, M. et al. Deep Learning-Based Cyber-Attack Detection for Industrial Control Systems. *IEEE Access*, v. 8, p. 94617–94626, 2020.

3. Ali, M.; Sharma, P. AI-Augmented Zero Trust Architecture: Enhancing Enterprise Cybersecurity Strategies. *Journal of Cybersecurity and Digital Trust*, v. 5, n. 1, p. 56–70, 2021.

4. Anderson, R.; Moore, T. The Economics of Information Security. *Science*, v. 314, n. 5799, p. 610–613, 2016.

5. Breadstein, L.; Singh, A. User and Entity Behavior Analytics for Insider Threat Detection. *International Journal of Information Security*, v. 18, n. 3, p. 245–260, 2019.

6. Buczak, A. L.; Guven, E. A Survey of Data Mining and Machine Learning Methods for Cyber Security Intrusion Detection. *IEEE Communications Surveys & Tutorials*, v. 18, n. 2, p. 1153–1176, 2016.

7. Fernandes, M.; Oliveira, T. Ransomware: evolução, impacto e desafios contemporâneos na segurança da informação [Ransomware: Evolution, Impact, and Contemporary Challenges in Information Security]. *Revista Brasileira de Segurança da Informação*, v. 10, n. 2, p. 45–62, 2021.

8. Garcia-Teodoro, P. et al. Intelligent Event Correlation for Large-Scale Cybersecurity Monitoring. *Computers & Security*, v. 103, p. 102–126, 2021.

9. Gartner. *Market Guide for Security Information and Event Management*. Gartner Research, 2020.

10. Goodfellow, I.; Bengio, Y.; Courville, A. *Deep Learning*. Cambridge: MIT Press, 2016.

11. Kim, J.; Park, S. Adaptive Cyber Threat Detection Through Continuous Machine Learning Optimization. *Journal of Network and Computer Applications*, v. 204, p. 103–121, 2022.

12. Mitchell, T. M. *Machine Learning*. New York: McGraw-Hill, 1997.

13. Moustafa, N.; Slay, J. The Evaluation of Network Anomaly Detection Systems: Statistical Methods and Machine Learning Models. *ACM Computing Surveys*, v. 52, n. 2, p. 1–40, 2019.

14. Russell, S.; Norvig, P. *Artificial Intelligence: A Modern Approach*. 4. ed. New York: Pearson, 2021.

15. Shone, N. et al. A Deep Learning Approach to Network Intrusion Detection. *IEEE Transactions on Emerging Topics in Computational Intelligence*, v. 2, n. 1, p. 41–50, 2018.

16. Singh, S.; Bangar, M.; Geetha, S.; Gupta, B. Anomaly-Based Intrusion Detection Using Machine Learning Techniques. *Computers & Security*, v. 87, p. 101–110, 2019.

17. Sommer, R.; Paxson, V. Outside the Closed World: On Using Machine Learning for Network Intrusion Detection. *IEEE Symposium on Security and Privacy*, p. 305–316, 2010.

18. Souza, R.; Mendes, E. Malwares polimórficos e os desafios para detecção baseada em assinaturas [Polymorphic Malware and Challenges for Signature-Based Detection]. *Journal of Cybersecurity Studies*, v. 4, n. 1, p. 23–37, 2020.

19. Stallings, W. *Network Security Essentials: Applications and Standards*. 6. ed. Boston: Pearson, 2019.

ISBN: 978-65-83849-24-3

Aurum EDITORA

CHAPTER 6

TOPOGRAPHY AND CELLULAR INTERACTION: APPLICATION OF ATOMIC FORCE MICROSCOPY IN STUDIES WITH TOXOPLASMA GONDII

https://doi.org/10.63330/aurumpub.021-006

Everson Reili de Souza Teles[1]

ABSTRACT

Toxoplasma gondii is an obligate intracellular protozoan capable of infecting a wide range of warm-blooded animals and remains a global health concern. Understanding the mechanisms underlying parasite–host cell interaction is essential for elucidating the initial steps of infection. In this study, we applied atomic force microscopy (AFM) combined with fluorescence microscopy to characterize, at nanometric resolution, the early stages of interaction between *T. gondii* tachyzoites (RH strain) and mammalian host cells (LLC-MK2 and HFF). A fixation protocol optimized with 4% formaldehyde and 1% glutaraldehyde ensured morphological preservation while maintaining suitable mechanical properties for topographical analysis. Quantitative evaluation of 100 cells per experiment revealed that, after 15 minutes of incubation, the majority of tachyzoites remained adhered to host cell surfaces, with fewer in contact or fully internalized. AFM imaging revealed host cell participation during invasion, showing localized membrane invaginations, conoid projections, and numerous actin-rich extensions resembling filopodia and tunneling nanotubes directed toward the parasite. Nanomechanical mapping demonstrated distinct height and elasticity patterns at the host–parasite interface, indicating active cytoskeletal remodeling and membrane engagement during internalization. These results highlight AFM as a powerful complementary approach to fluorescence microscopy, providing unprecedented insights into the topography, elasticity, and dynamic remodeling of host cell membranes during *T. gondii* invasion. Understanding these structural and mechanical interactions contributes to elucidating the early determinants of infection and may aid in identifying novel therapeutic targets.

Keywords: *Toxoplasma gondii*; Atomic force microscopy; Host–parasite interaction; Cell invasion; Nanomechanics; Cytoskeletal remodeling.

[1] Master of Science in Biomedical Sciences
Federal University of Rio de Janeiro - UFRJ
Hertha Meyer Cellular Ultrastructure Laboratory, Precision Medicine Research Center, Carlos Chagas Filho Institute of Biophysics, National Center for Structural Biology and Bioimaging
E-mail: everson.rsteles@gmail.com

INTRODUCTION

Toxoplasma gondii is an obligate intracellular protozoan of worldwide distribution, being highly efficient in its invasion process, with the ability to infect a wide variety of homeothermic vertebrates, birds, and economically important animals (Dubey, 2010; Montoya & Liesenfeld, 2004). In Brazil, *T. gondii* infection shows high prevalence across all regions, affecting both humans and domestic animals (Dubey et al., 2012; Pena et al., 2008). The invasion process of *T. gondii* into host cells occurs in less than 20 seconds and is characterized by an active penetration mechanism mediated by secretory proteins from apical complexes such as micronemes, rhoptries, and dense granules (Carruthers & Boothroyd, 2007; Lorenzi et al., 2016). A moving junction is formed as a result of the strong association between the apical end of the parasite and the host cell surface, during which the parasite secretes adhesion and anchoring proteins into the host cell membrane, leading to its internalization within a parasitophorous vacuole (Dubey, 2021; de Souza & Portes in Martins-Duarte & Adesse, 2021).

Among the methodologies available for morphological and topographical studies of these interactions, atomic force microscopy (AFM) stands out as a promising tool. This technique enables high-resolution visualization of the cell surface, allowing three-dimensional and nanomechanical analysis of events such as adhesion, membrane invagination, and the formation of cytoskeleton-associated structures during the invasion process (Binnig et al., 1986; Hoh & Engel, 1993; Cappella & Dietler, 1999). AFM has been successfully applied to the study of protozoa such as *Plasmodium* and *Giardia*, and more recently, to investigations of *T. gondii* interactions with host cells (de Souza & Rocha, 2011).

In this study, we employed atomic force microscopy to characterize, with high resolution, the initial events of interaction between tachyzoites of the *T. gondii* RH strain and epithelial LLC-MK2 cells and HFF fibroblasts. The objective was to map, at topographic and nanomechanical levels, the alterations in the host cell surface and the structures involved in moving junction formation, aiming to deepen the morphological understanding of this crucial infection process.

Understanding the initial interaction between a host cell and an intracellular parasite is essential, as the determinants involved can be explored as potential therapeutic targets to help block infection at its earliest stages, contributing to the development of innovative treatment strategies. Considering the existence of different possible invasion processes of the parasite, we sought to describe in greater detail the events associated with invasion. For this purpose, tachyzoites of the RH strain and LLC-MK2 and HFF cell lines were used. Through synchronization of entry events, we chose to perform our analyses after 15 minutes of interaction. The analyses included fluorescence microscopy to quantify tachyzoite entry into host cells and atomic force microscopy. After synchronization, we observed the host cell's participation in parasite internalization, numerous host cell projections involved during entry, and nanotubes projected from the host cell toward the parasite.

MATERIALS AND METHODS

HOST CELLS

Two distinct host cell lines were used: rhesus monkey (Macaca mulatta) kidney epithelial cells, LLC-MK2 (ATCC – CCL7, Rockville, MD/USA), cultured in RPMI 1640 medium supplemented with 10% fetal bovine serum; and human foreskin fibroblast cells, HFF1, cultured in complete Dulbecco's Modified Eagle Medium (DMEM; Invitrogen, Carlsbad, CA), supplemented with 10% heat-inactivated fetal bovine serum (Hyclone, Logan, UT), 1% streptomycin and penicillin, and 2 mM L-glutamine (Sigma). Cultures were maintained at 37 °C in a humidified atmosphere with 5% CO_2.

PARASITES

T. gondii RH strain tachyzoites were maintained by serial passages in confluent LLC-MK2 cells. Two to three days post-infection, parasites obtained from the supernatant were centrifuged at 1000 × g for 10 minutes, resuspended in RPMI medium, and counted using a Neubauer chamber.

PARASITE–HOST CELL INTERACTION

One day before the interaction experiments, 5×10^5 cells were plated on sterile round glass coverslips in 24-well plates or distributed into 25 cm^2 culture flasks. Cells were then washed three times with phosphate-buffered saline (PBS), and parasites were added at a ratio of 50:1 (parasites:cell). Subsequently, the cultures were incubated at 4 °C for 30 minutes to synchronize parasite invasion. Afterward, cells were transferred to a 37 °C incubator and incubated for approximately 19 minutes. At this stage, with the medium reaching around 20 °C, the parasite regains motility and interacts with the cell, thereby synchronizing the entry events. After 15 minutes of interaction, cells were processed for microscopy analyses.

FLUORESCENCE MICROSCOPY

After synchronization of entry events between *T. gondii* and host cells, samples were fixed in 4% formaldehyde in PBS buffer (pH 7.5) for 15 minutes at room temperature. Cells were washed three times with PBS (pH 7.5) and permeabilized with 0.1% Triton X-100 in PBS containing 3% bovine serum albumin (BSA) for 10 minutes, repeated three times. After permeabilization, samples were again washed three times with PBS (pH 7.5) and incubated overnight at 4 °C with a primary anti-SAG (surface antigen of tachyzoite) antibody diluted 1:500. The next day, samples were washed three times with PBS (pH 7.5) and incubated with Alexa Fluor 546-conjugated anti-mouse secondary antibody (1:1000) for 2 hours at room temperature, protected from light. Observations were performed in confocal mode using a Zeiss Elyra PS.1 LSM 710 microscope (Germany).

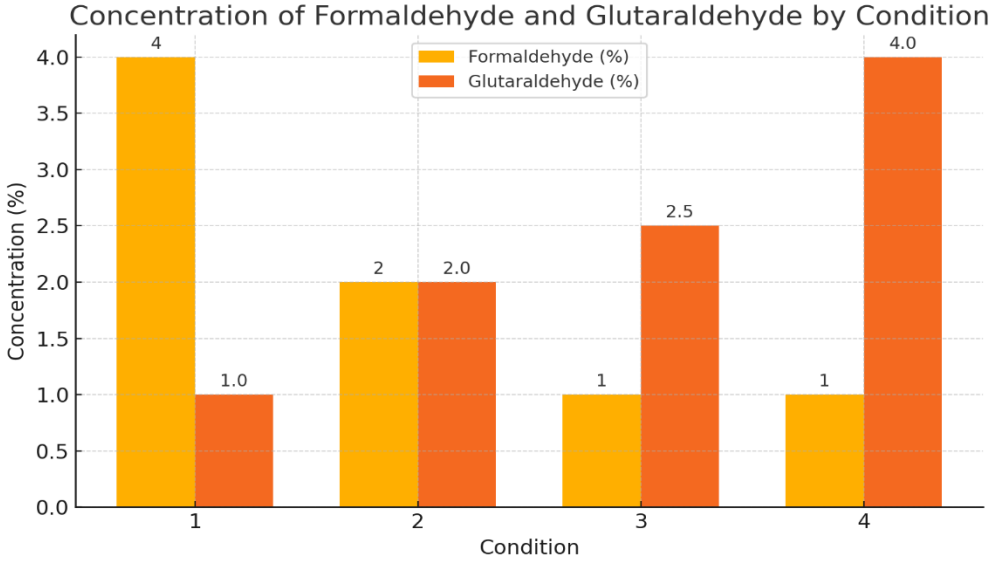
ATOMIC FORCE MICROSCOPY (AFM)

Samples were fixed in a solution containing 1% glutaraldehyde and 4% formaldehyde in sodium phosphate buffer (pH 7.2) for 1 hour, washed with PBS (pH 7.2), and post-fixed for 1 hour in 1% osmium tetroxide in phosphate buffer, protected from light. Cells were dehydrated in increasing concentrations of acetone (30% to 100%) for 10 minutes at each step and dried using CO_2 critical point drying. Images were obtained at room temperature using a Bruker Dimension Icon Scanning Probe Microscope. Cantilevers with spring constants between 0.4 N/m and 2 N/m were used. For nanomechanical property analysis, full cantilever calibration was performed. To minimize damage and noise, images were acquired with a scanning frequency of approximately 1 Hz and a resolution of 512 × 512 pixels. To assist in analyses, the data matrix that generates flattened images was transformed into a three-dimensional visualization, providing better interpretation of AFM-obtained data (de Souza & Rocha, 2011).

RESULTS

The ultrastructure of *Toxoplasma gondii* invasion into host cells was observed using fluorescence microscopy and topographic images generated by AFM, in which the initial interaction events and even the invasion process of the parasite were analyzed, clearly showing host cell participation. Proper fixation is critical for preserving cellular morphology and obtaining high-quality images. In this study, different combinations of formaldehyde and glutaraldehyde were tested to identify the most effective protocol for maintaining the structural integrity of the samples, as shown in Figure 1**.**

Figure 1**.** Concentrations of formaldehyde and glutaraldehyde used under different experimental conditions. Each condition corresponds to a specific combination of fixative concentrations applied to cell samples. Bars represent the percentage of each fixative. Data are representative of standardized protocols for morphological preservation.

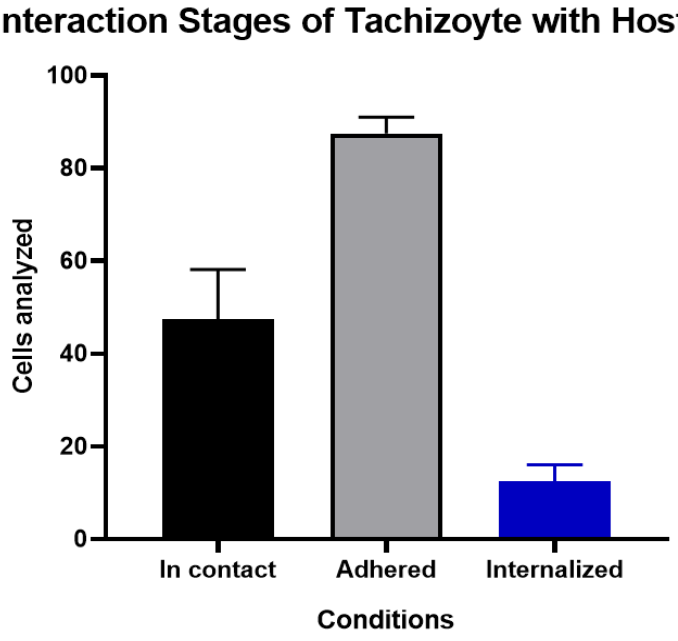


Source: Author's own work (2025).

Among the tested formulations, high concentrations of glutaraldehyde (≥2.5%) ensured excellent ultrastructural preservation but compromised topography. Balanced combinations (2% FA / 2% GA) provided good structural preservation; however, when the cantilever came into direct contact with the sample, significant topographical information was lost, reducing data fidelity. In contrast, the 4% FA / 1% GA formulation proved most suitable for this assay, as it preserved the overall morphology of both host cells and parasites while minimizing excessive stiffening. This allowed accurate visualization of the host–parasite interface and maintained suitability for morphological studies. Thus, although GA-rich fixatives are preferable for high-resolution electron microscopy, the final choice of 1% GA + 4% FA represented the best strategy to balance structural preservation with the requirements of *T. gondii*–host interaction studies by AFM.

With the fixation protocol for AFM established, 100 cells per experiment were analyzed in triplicate, and *T. gondii* tachyzoites were classified according to interaction stage: adhesion, contact, and internalization. After 15 minutes of incubation, parasites were predominantly adhered to the host cell surface, followed by those in contact and a smaller number of internalized parasites. Statistical analysis (ANOVA with Tukey's test) revealed significant differences between groups ($p < 0.05$), indicating that the experimental time was sufficient to capture distinct phases of parasite entry, with emphasis on early adhesion events (figure 2).

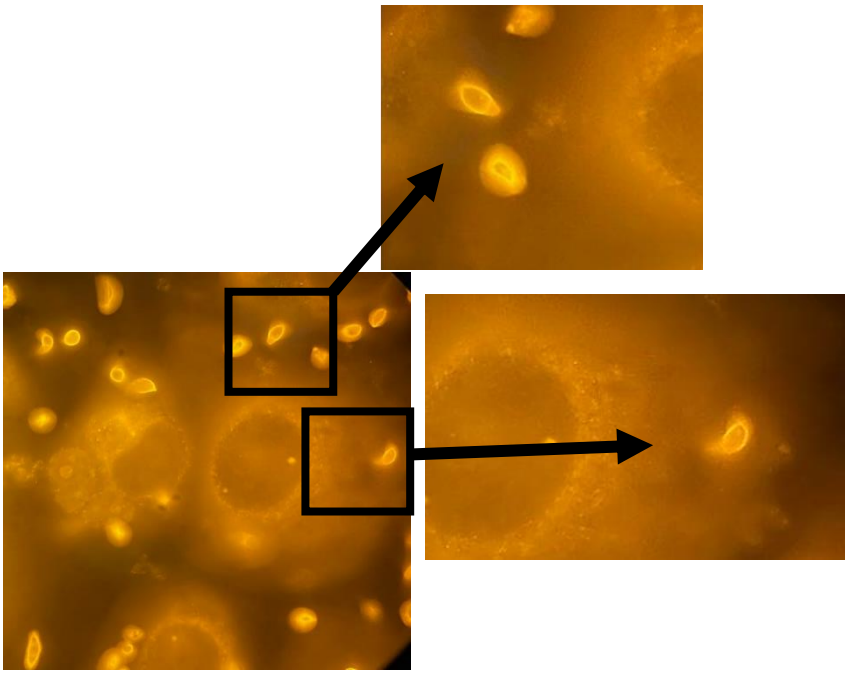
Figure 2: Quantification of *Toxoplasma gondii* tachyzoites classified according to their interaction with host cells after 15 minutes of incubation. Parasites were grouped into three categories: adhered (attached to the cell surface), in contact (in the process of entry), and internalized (completely inside the cell). Data represent the mean ± standard deviation of three independent experiments, with n = 100 cells analyzed per condition. Statistical analysis was performed by ANOVA followed by Tukey's test, with $p < 0.05$ considered significant.



Source: Author's own work (2025).

Fluorescence microscopy was used to visualize the invasion process. Labeling of the surface antigen (SAG) allowed visualization of the initial interaction between the tachyzoite and the host cell. In the obtained images, the host cell membrane showed a localized invagination at the point of contact with the parasite, indicative of the formation of the moving junction—an essential structure for the active internalization process promoted by *T. gondii*.(figure 3)

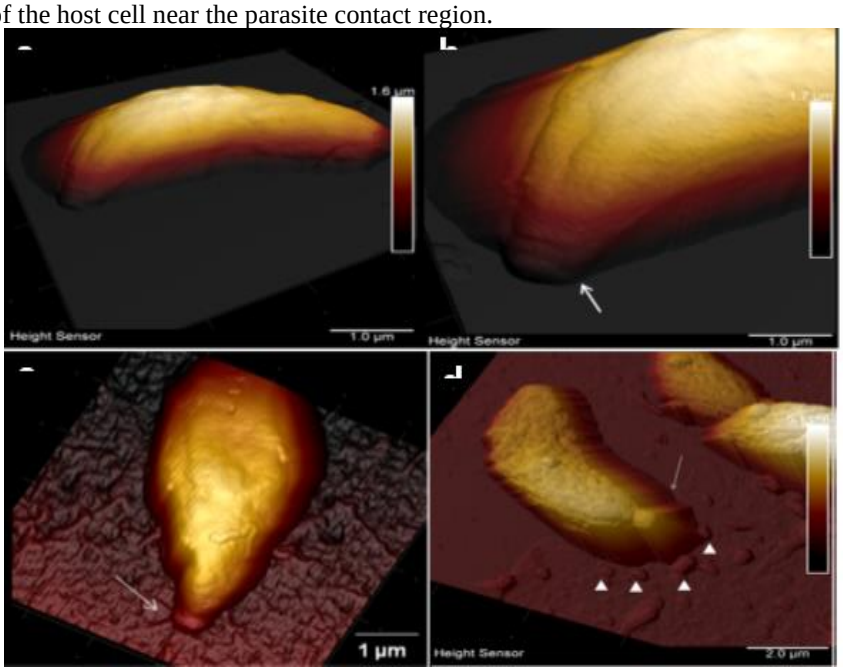
Figure 3. Fluorescence microscopy showing labeling of *Toxoplasma gondii* surface antigen (SAG) during the initial invasion events. Membrane invagination of the host cell is observed at the point of contact with the tachyzoite, suggesting. The site of formation of the structure known as the moving junction.



Source: Author's own work (2025).

In the early stages of the invasion process, which consists of cell recognition (**Figure 4a**) followed by parasite adhesion (**Figure 4b**), conoid projection occurs (**Figure 4c**) together with secretion of proteins required for moving junction formation. During these initial events, membrane projections from the host cell surrounding the parasite were also observed (**Figures 4c and 4d**).

Figure 4. Ultrastructure of *T. gondii* by AFM interacting with LLC-MK2 cells. a. Fixed with formaldehyde after 15 minutes of interaction, showing the entire body of the tachyzoite with conoid (arrow) interacting with the host cell. b. Higher magnification of the conoid projection (arrow).c. Arrow indicates the conoid on the host cell surface. d. Arrowhead shows membrane projections of the host cell near the parasite contact region.



Source: Author's own work (2025).

In **Figure 5**, filopodia-like projections emitted by the host cell are observed in regions of contact with *T. gondii*. AFM image analysis revealed distinct height and elasticity signals in these areas, indicating the presence of possible filaments directed toward the parasite. These structures are consistent with tunneling nanotubes—actin-rich extensions commonly associated with adhesion and cellular recognition events.

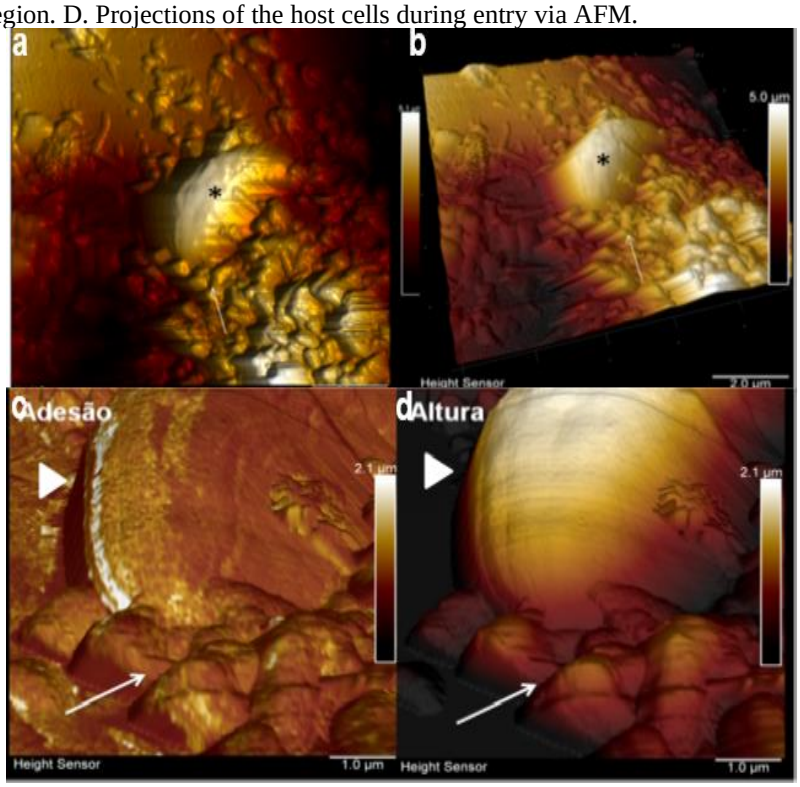
Figure 5. Filopodia-like projections emitted by the host cell in contact regions with the parasite. Height and elasticity signals near these regions suggest possible filaments emitted from the host cell (arrow). Scale bar: 1 µm.

Source: Author's own work (2025).

Topographical analysis revealed lateral internalization of the parasite, with the tachyzoite assuming a “half-moon” shape (**Figure 6a**). Multiple host cell membrane projections were also observed

in this region (**Figure 6b**), appearing in all parasite-contact areas, forming a pattern supported by adhesion and height data (**Figures 6c and 6d**).

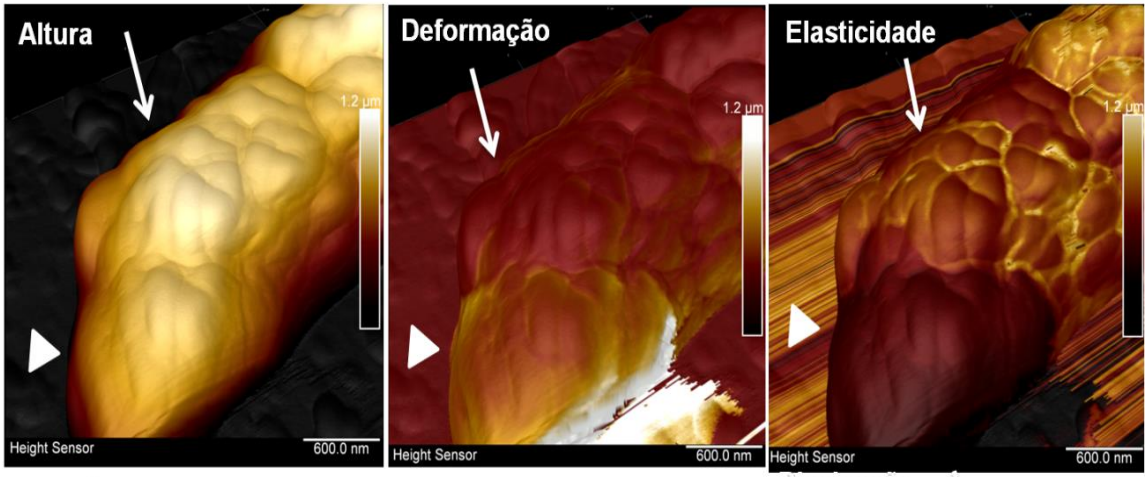
Figure 6. Three-dimensional representation of height images during tachyzoite invasion, as observed using a single-tip probe. A. The arrows indicate projections of the host cell, and the lateral orientation of the parasite is marked with an asterisk during entry. C. At the arrowhead, the tachyzoite is surrounded by the host cell membrane, indicated by an arrow, with numerous projections in this entry region. D. Projections of the host cells during entry via AFM.



Source: Author's own work (2025).

Surface density in the tachyzoite entry region was higher compared to adhesion-only regions. In **Figure 7**, elasticity signal readings allowed differentiation between host cell membrane regions—those with higher elasticity signals corresponding to membrane enveloping the parasite, while the non-internalized portion emitted lower elasticity signals.

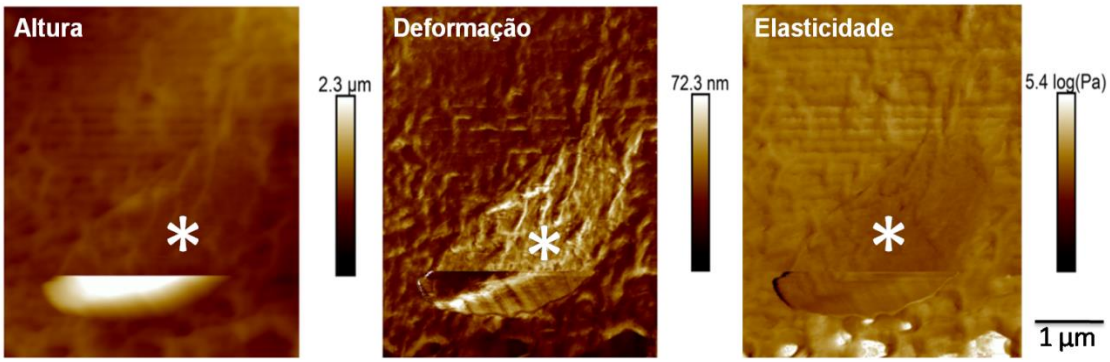
Figure 7**.** Host cell membrane surrounding *T. gondii* tachyzoites observed by AFM with height, deformation, and elasticity data. Arrow indicates the host cell membrane enveloping the parasite, with the arrowhead showing the partially unengulfed parasite body.



Source: Author's own work (2025).

During scanning, the cantilever probe swept across the parasite; upon its removal, deformation signals were detected in the area previously occupied by the parasite, indicating possible rearrangement of the host cell membrane surface at the adhesion and contact site **(**Figure 8**).**

Figure 8. Host cell surface after scanning of the parasite by the probe. The asterisk marks the area that, before scanning, corresponded to the tachyzoite anchoring site on the host cell, which was unexpectedly removed during the cantilever process.



Source: Author's own work (2025).

DISCUSSION

The study of interactions between pathogenic protozoa and host cells—particularly those capable of penetrating and replicating intracellularly—has been the focus of extensive research. In the case of *Toxoplasma gondii*, evidence indicates that it can be internalized by various cell types; however, mere entry does not guarantee successful infection and intracellular multiplication. Successful infection requires an active invasion mechanism involving the parasite's apical organelles. In this work, we analyzed observable data from the early interaction process using atomic force microscopy, focusing on

the first fifteen minutes of interaction, a period previously shown to involve diverse host cell morphologies (Teles *et al*., 2023).

The choice of fixative concentration is critical for morphological preservation, antigenicity, and cellular rigidity, particularly in studies of interactions between mammalian cells and *T. gondii*. In search of an efficient and standardized fixation protocol, different combinations of formaldehyde (FA) and glutaraldehyde (GA) were evaluated to optimize morphological preservation without compromising structural integrity. Comparative analysis of four formulations—(1) 4% FA + 1% GA, (2) 2% FA + 2% GA, (3) 1% FA + 2.5% GA, and (4) 1% FA + 4% GA—revealed that high GA concentrations, although promoting excellent ultrastructural preservation, caused excessive stiffening that limited elasticity analyses.

Conversely, the 4% FA + 1% GA formulation provided the best overall performance: it preserved cellular morphology, prevented material loss during cantilever contact, and minimized structural artifacts. This balance between fixatives and sample response made the combination ideal for AFM-based topographical analysis and was thus adopted as the standard protocol for subsequent analyses. Traditional microscopic techniques have long been employed to study *T. gondii*–host cell interactions (Dubey, 2021; de Souza & Portes in Martins-Duarte & Adesse, 2021; Teles, 2023). However, most focus on parasite development within the parasitophorous vacuole.

Our AFM observations support the involvement of the host cell during interaction with the tachyzoite. This methodology was initially applied by Aikawa (1997) to examine *Plasmodium*–erythrocyte interactions and later extended to other protozoa (de Souza & Rocha, 2011). Signals captured by the probe indicated increased elasticity in regions where the tachyzoite was partially covered by the host cell membrane. Considering that *T. gondii* possesses a trilaminar pellicle (Cintra & de Souza, 1985), this overlap explains the observed elasticity increase at probe–sample contact, while reduced height and elasticity signals in the lower region suggest areas of the parasite body not yet fully internalized.

Numerous alterations on the host cell surface were detected during scanning. Depending on morphology and cellular context, these protrusions may be classified as microvilli, lamellipodia, filopodia, or growth cones (Condeelis, 1993). The biogenesis of these structures depends on cytoskeletal organization and plays essential roles in cell motility and endocytosis (Pantaloni *et al*., 2001), processes also associated with passive entry of *T. gondii* (Portes *et al*., 2019).

Protrusive processes require a specialized actin filament system driving membrane movement. Actin filaments are polarized and, upon myosin binding, elongate rapidly, pushing the membrane forward (Pantaloni et al., 2001). Although both are cytoskeleton-related membrane projections, filopodia have been described in numerous biological contexts.

Using atomic force microscopy, we observed that, following scanning of an adhered tachyzoite, the host cell membrane surface underwent reorganization, indicating parasite anchoring. During *T. gondii*–host cell interaction, intense remodeling occurs at the contact area, involving the aforementioned structures and others, underscoring the need for new approaches and techniques to fully understand host–parasite interactions.

REFERENCES

1. AIKAWA, M. Studies on falciparum malaria with atomic-force and surface-potential microscopes. Annals of Tropical Medicine and Parasitology, v. 91, n. 7, p. 689–692, 1997. DOI: https://doi.org/10.1080/00034989760419

2. BINNIG, G.; QUATE, C. F.; GERBER, C. Atomic force microscope. Physical Review Letters, v. 56, n. 9, p. 930–933, 1986.
DOI: https://doi.org/10.1103/PhysRevLett.56.930

3. BHUSHAN, B. Springer Handbook of Nanotechnology. 3. ed. Berlin: Springer, 2010. ISBN: 978-3-642-02525-9.

4. CAPPELLA, B.; DIETLER, G. Force-distance curves by atomic force microscopy. Surface Science Reports, v. 34, n. 1–3, p. 1–104, 1999.
DOI: https://doi.org/10.1016/S0167-5729(99)00003-5

5. CARRUTHERS, V. B.; BOOTHROYD, J. C. Pulling together: an integrated model of Toxoplasma cell invasion. Current Opinion in Microbiology, v. 10, n. 1, p. 83–89, 2007. DOI: https://doi.org/10.1016/j.mib.2006.06.017

6. CINTRA, W. L.; DE SOUZA, W. Distribution of intramembranous particles and filipin-sterol complexes in the cell membranes of Toxoplasma gondii. European Journal of Cell Biology, v. 37, p. 63–69, 1985.

7. CONDEELIS, J. Life at the Leading Edge: The Formation of Cell Protrusions. Annual Review of Cell and Developmental Biology, v. 9, p. 411–444, 1993.
DOI: https://doi.org/10.1146/annurev.cb.09.110193.002211

8. DE SOUZA, W.; ROCHA, G. M. Atomic force microscopy: a tool to analyze the structural organization of pathogenic protozoa. Trends in Parasitology, v. 27, n. 4, p. 160–167, 2011. DOI: https://doi.org/10.1016/j.pt.2010.12.010

9. DUBEY, J. P. Toxoplasmosis of Animals and Humans. 2. ed. Boca Raton: CRC Press, 2010. ISBN: 978-1420087368.

10. DUBEY, J. P. Toxoplasmosis of Animals and Humans. 3. ed. Boca Raton: CRC Press, 2021. DOI: https://doi.org/10.1201/9781003199373

11. DUBEY, J. P.; RAJENDRAN, C.; FERREIRA, L. R.; MARTINS, J.; KWOK, O. C. H.; HILL, D. E.; SU, C. Global status of Toxoplasma gondii infection in humans and animals. Parasitology, v. 139, n. 11, p. 1375–1424, 2012.
DOI: https://doi.org/10.1017/S003118201200115X

12. HOH, J. H.; ENGEL, A. Atomic force microscopy for high-resolution imaging in cell biology. Tre nds in Cell Biology, v. 3, n. 11, p. 208–213, 1993.
DOI: https://doi.org/10.1016/0962-8924(93)90105-A

13. LORENZI, H.; KHAN, A.; BEHNKE, M. S.; NISSEN, J.; LEYVA, A.; MACKENZIE, B. A.; GRIGG, M. E.; BOOTHROYD, J. C.; SIBLEY, L. D. Local admixture of amplified and diversified secreted

pathogenesis determinants shapes mosaic Toxoplasma gondii genomes. Nature Communications, v. 7, p. 10147, 2016.
DOI: https://doi.org/10.1038/ncomms10147

14. MARTINS-DUARTE, É. dos S.; ADESSE, D. (org.). Toxoplasma gondii: Biology and Role in Health and Disease. New York: Nova Science Publishers, 2021. Capítulo: PORTES, J. A.; DE SOUZA, W. Toxoplasma gondii Entry Mechanisms and Establishment of the Parasitophorous Vacuole, p. 43–76.

15. MONTOYA, J. G.; LIESENFELD, O. Toxoplasmosis. The Lancet, v. 363, n. 9425, p. 1965–1976, 2004.
DOI: https://doi.org/10.1016/S0140-6736(04)16412-X

16. MORRIS, V. J.; KIRBY, A. R.; GUNNING, A. P. Atomic Force Microscopy for Biologists. London: Imperial College Press, 2010.
DOI: https://doi.org/10.1142/p644

17. PANTALONI, D.; LE CLAINCHE, C.; CARLIER, M. F. Mechanism of actin-based motility. Science, v. 292, n. 5521, p. 1502–1506, 2001.
DOI: https://doi.org/10.1126/science.1059975

18. PENA, H. F. J.; GENNARI, S. M.; DUBEY, J. P.; SU, C. Toxoplasma gondii infection in cats from São Paulo State, Brazil: seroprevalence, oocyst shedding, and genotyping. Veterinary Parasitology, v. 160, n. 1–2, p. 180–185, 2009.
DOI: https://doi.org/10.1016/j.vetpar.2008.10.093

19. PORTES, J. A.; CARNEIRO, A. B.; DE SOUZA, W.; SEABRA, S. H. Toxoplasma gondii mechanisms of entry into host cells. Frontiers in Cellular and Infection Microbiology, v. 10, 2020, article 605750.
DOI: https://doi.org/10.3389/fcimb.2020.605750

20. TELES, E. R. de S.; PORTES, J. S; DE SOUZA, W. New morphological observations on the initial events of interaction between Toxoplasma gondii and mammalian host cells using atomic force microscopy. Veterinary Parasitology, v. 312, 2023, article 109869.
DOI: https://doi.org/10.1016/j.vetpar.2023.109869

ISBN: 978-65-83849-24-3

DANCE THERAPY AS AN INSTRUMENT FOR PROMOTING PHYSICAL AND EMOTIONAL HEALTH: PRACTICES, BENEFITS, AND PERCEPTIONS BASED ON EXPERIENCES IN DANCE SCHOOLS IN BRASÍLIA

https://doi.org/10.63330/aurumpub.021-007

Rodrigo Thomé de Moura[1]

ABSTRACT

Dance therapy has emerged as a valuable therapeutic approach to promote physical and emotional health through movement. The objective of this study was to analyze dance therapy, exploring its historical trajectory, theoretical foundations, and applications in Brazil, with an emphasis on dance schools as therapeutic environments. The research was conducted through a qualitative bibliographic review involving books, scientific articles, and relevant institutional documents. The results indicated that dance therapy, by integrating body and emotion, demonstrated effectiveness in strengthening subjective expression and well-being, especially in non-clinical contexts such as schools and communities. It was found that dance practices in educational environments not only foster socialization but also significantly contribute to individuals' overall health. The study highlighted the importance of these expressive practices in coping with stress and anxiety, particularly in contemporary urban settings. The conclusions emphasized the potential of dance therapy as a health-promoting instrument, suggesting that adequate conditions in schools and community spaces can facilitate experiences of human development, showing that dance goes beyond technical learning, functioning as a means of expression and self-care.

Keywords: Dance therapy; Health; Emotion; Community; Expression.

[1] Postgraduate Studies in Dance Therapy
Prisma
E-mail: rodrigofsw@gmail.com

INTRODUCTION

Dance, as a bodily language and sociocultural phenomenon, occupies a central place in human history, acting as a form of expression, communication, and production of meaning. In recent years, the field of dance therapy has gained increasing visibility in Brazil and worldwide, particularly for its ability to integrate body, emotion, and subjectivity in therapeutic and educational processes. Authors such as Marian Chace, Trudi Schoop, and Mary Whitehouse, pioneers of Dance/Movement Therapy, demonstrated that movement can foster bonds, expand body awareness, and promote profound emotional reorganizations (Chaiklin & Schmais, 1993; Whitehouse, 1979).

In Brazil, this understanding dialogues with studies on corporeality, such as those by Merleau-Ponty (1999) and Le Breton (2011), who view the body as the center of human experience and mediator of social relations.

Given this scenario, there arises the need to investigate how dance, especially in non-clinical spaces—such as dance schools, community centers, and sociocultural initiatives—can act as an instrument for promoting physical and emotional health. **The hypothesis guiding this study is that dance, when developed in educational and community environments, significantly contributes to well-being, socialization, and the strengthening of subjective expression,** approaching therapeutic principles even outside the traditional context of formal therapy. Thus, practices developed in schools such as Planet, in Brasília, may represent hybrid spaces where art, care, and coexistence intertwine, fostering experiences of human development.

The general objective of this work is to analyze dance therapy as a tool for health promotion, investigating its origin, theoretical foundations, applications in the Brazilian context, and the role of dance schools as potentially therapeutic environments. Specifically, the study seeks to: (a) present the historical evolution of dance therapy and its main theoretical contributions; (b) discuss the relationship between body, movement, and health based on philosophical, anthropological, and psychological literature; (c) examine how dance therapy has been incorporated into different contexts in Brazil; and (d) understand how dance schools and community spaces can act as environments of care and well-being promotion, with emphasis on the Planet School.

The justification for this study lies in the expansion of interdisciplinary understanding of health, which has shifted its focus from a biomedical model to integrative conceptions, recognizing the importance of the body, expression, and aesthetic experience for emotional and psychosocial balance. Furthermore, expressive bodily practices have proven relevant in the face of increasing disorders related to stress, social isolation, and anxiety, especially in large urban centers. Thus, investigating dance therapy and its socio-community applications contributes to strengthening innovative, accessible, and culturally situated care practices.

The work was developed through qualitative bibliographic research, based on books, scientific articles, and institutional documents, including works by Chace, Whitehouse, Schoop, Merleau-Ponty, Le Breton, Laban, and documents from the American Dance Therapy Association (ADTA). The structure of the study is organized into four main sections: the first discusses the origin and evolution of dance therapy; the second addresses body, movement, and health; the third examines the Brazilian context; and the fourth analyzes dance schools as therapeutic spaces, including a description of the Planet School. This organization allows for an integrated understanding of theoretical foundations, contemporary practices, and the social and therapeutic implications of dance.

METHODOLOGY

The methodology adopted in this work was based on a qualitative approach and bibliographic research, aiming to provide a comprehensive understanding of dance therapy and its applications in the Brazilian context. The first step involved the careful selection of relevant sources, including books, scientific articles, and institutional documents, which address both the theoretical foundations of dance therapy and its contemporary practices.

Fundamental authors in the field of dance therapy were consulted, such as Marian Chace, Trudi Schoop, and Mary Whitehouse, whose historical and methodological contributions established the foundations of the discipline. In addition, texts discussing the relationship between body, movement, and health were analyzed, including works by Merleau-Ponty and Le Breton, which deepen the understanding of corporeality as a central axis in human experience. This theoretical analysis was complemented by specific studies portraying the insertion and results of dance therapy in educational and community contexts.

The research was organized into four main sections: the first addressed the origin and evolution of dance therapy, highlighting its roots in the early 20th century; the second examined the interrelationship between body, movement, and health, emphasizing the importance of corporeality in promoting well-being; the third focused on the Brazilian context, discussing dance therapy practices in institutions and their contribution to collective health; and the fourth section specifically analyzed dance schools, such as the Planet School, as potentially therapeutic spaces.

In addition to the bibliographic review, the work also considered institutional documents, guidelines from associations such as the American Dance Therapy Association (ADTA), and contemporary research highlighting the effectiveness of these practices in non-clinical environments. The inclusion of different perspectives and contexts facilitated a richer and more varied analysis of dance therapy.

Through this methodology, the work sought not only to describe existing practices but also to understand the perceptions and experiences of individuals involved in dance therapy, allowing for a comprehensive view of the potential of this field in strengthening emotional and community health. The qualitative approach enabled a critical reflection on the contributions of dance therapy and its relevance in a contemporary scenario marked by emotional and social challenges. This methodology, therefore, was fundamental for achieving the study's objectives and for ensuring that the conclusions presented could be supported by a solid theoretical basis and practical evidence on the impact of dance therapy on people's lives..

DEVELOPMENT

ORIGIN AND EVOLUTION OF DANCE THERAPY

Dance therapy, also known as Dance/Movement Therapy (DMT), is a practice that integrates movement, bodily expression, and psychotherapeutic processes. Its origin is linked to the development of modern dance in the early 20th century, when artists and scholars began to understand movement not only as an aesthetic form but also as emotional manifestation and non-verbal communication. In this context, dance came to be seen as a therapeutic channel capable of promoting self-knowledge, mind-body integration, and psychological well-being.

The field became consolidated particularly through the contributions of pioneers such as Marian Chace, Trudi Schoop, and Mary Whitehouse, whose work shaped the theoretical and methodological foundations of dance therapy. Marian Chace, considered the principal founder of DMT in the United States, developed her practice upon observing that her dance students sought not only technical improvement but also emotional expression and a sense of care. In her work with psychiatric patients at St. Elizabeth's Hospital, Chace realized that movement fostered engagement, communication, and group cohesion, contributing to the reduction of isolation and mental suffering (Chaiklin & Schmais, 1993).

Another essential figure was Trudi Schoop, a Swiss dancer and choreographer, who brought to the therapeutic field her understanding of dance as dramatic expression. Schoop employed humor, theatricality, and spontaneous movement as means to access repressed emotions and stimulate psychocorporal reorganization. Her work with patients with schizophrenia demonstrated that expressive movement could restore social bonds and expand body awareness (Levy, 1988).

Mary Whitehouse, influenced by Carl Gustav Jung's analytical psychology, created the method known as Movement in Depth or Authentic Movement. For her, dance emerged from the unconscious through spontaneous movements capable of revealing deep psychic content. Whitehouse argued that by following authentic bodily impulses, the individual approached their inner truth, promoting emotional integration and psychological development (Whitehouse, 1979).

With the advancement of these practices, dance therapy gained institutional recognition and became consolidated as a profession and research area. The American Dance Therapy Association (ADTA), founded in 1966, defined dance therapy as "the psychotherapeutic use of movement to promote emotional, cognitive, physical, and social integration of the individual" (ADTA, 2022). This definition underscores the clinical and holistic nature of the practice, which involves not only the moving body but also symbolic, relational, and subjective processes.

Over the decades, dance therapy expanded to various contexts—hospitals, schools, mental health clinics, community environments, and integrative arts spaces—demonstrating effectiveness across different age groups and populations with diverse needs. The evolution of the field keeps alive the articulation between art and science, body and mind, emotion and movement, reaffirming dance as a universal language and a powerful therapeutic instrument.

BODY, MOVEMENT, AND HEALTH

The body, movement, and health constitute a field of study that articulates philosophy, anthropology, psychology, and therapeutic practices. Contemporary understanding of corporeality goes beyond the biological or mechanistic view of the body, recognizing it as the center of human experience, a locus of perceptions, meanings, and subjective expressions. Authors such as Merleau-Ponty and Le Breton have expanded this discussion, contributing to the notion of the body as a fundamental dimension of existence and not merely as physical support.

For Merleau-Ponty (1999), the body is the means by which the subject relates to the world. He proposes the concept of corporeality as a perceptual structure that integrates sensations, actions, and meanings. Thus, bodily experience is not separate from consciousness but constitutes the very basis of perception and subjectivity. In this sense, the body is not merely an object but a bodily subject, capable of expressing and producing meaning through movement.

In contemporary anthropology, David Le Breton (2011) reinforces this perspective by arguing that the body is a symbolic and cultural construction. For the author, every bodily action is permeated by social, emotional, and historical meanings.

Corporeality, therefore, is not limited to the physiological dimension; it involves ways of being and existing in the world, in which the body functions as language and as a mediator of human relationships.

The relationship between body, movement, and subjectivity also finds support in the contributions of Rudolf Laban, one of the leading theorists of movement. For Laban (1978), expressive movement is a profound form of communication that reveals internal aspects of the individual. He developed analytical systems such as Effort and Space, which demonstrate how movement qualities—such as weight, flow,

time, and direction—reflect emotional states and subjective processes. Thus, the body becomes an instrument of expression and psychic reorganization.

In the therapeutic field, this integrated understanding of the body underpins practices such as dance therapy, art therapy, and psychocorporal approaches. The dynamic between movement and emotion is seen as bidirectional: movements can express pre-existing feelings but can also evoke, transform, and regulate emotions. Through bodily action, individuals access memories, sensations, relational patterns, and unconscious content, fostering psychological well-being and personal development. This relationship is grounded in studies of somatic psychology and integrative therapies, which show that movement helps reduce bodily tension, expand emotional awareness, and strengthen social and affective bonds.

Thus, understanding body, movement, and health implies recognizing that well-being is not merely the absence of disease but a state of balance among physical, emotional, cognitive, and social dimensions. Corporeality, in this context, provides a solid foundation for therapeutic practices that integrate art, science, and subjectivity, reaffirming the body as a space of expression, healing, and meaning-making.

DANCE THERAPY IN THE BRAZILIAN CONTEXT

Dance therapy in the Brazilian context developed through dialogue between expressive bodily practices, international influences of Dance/Movement Therapy, and the cultural richness of movement in Brazil. Since the last decades of the 20th century, the field has been consolidating as an integrative practice present in various social, clinical, and educational spaces, accompanying the expansion of public health policies, complementary therapeutic approaches, and contemporary demands for comprehensive care.

In contemporary practices, dance therapy has expanded to psychological and multidisciplinary clinics, where it acts as a complementary resource in treating emotional disorders, relational difficulties, psychological suffering, and psychocorporal issues. In schools, dance therapy appears in projects for emotional education, school inclusion, and psychomotor development, contributing to strengthening socio-emotional skills, self-esteem, and students' creative expression. In community centers, such as CRAS, CAPS, cultural institutions, and civil society organizations, the practice is used to promote well-being, strengthen community ties, and encourage social participation, especially among older adults, women, children, and people in situations of social vulnerability.

The inclusion of dance therapy in collective health strongly dialogues with the national movement of Integrative and Complementary Health Practices (PICS), recognized by the Ministry of Health since 2006. Although dance therapy is not officially listed as a PICS, it falls within the same field of bodily and expressive therapies that value expanded care, therapeutic bonding, and integrality. Health professionals

have applied its principles in therapeutic groups, community workshops, and health promotion programs, strengthening approaches that consider the body as a central dimension of care (Brasil, 2017).

In education, dance therapy has gained space in pedagogical projects that articulate art, movement, and human development. Influenced by authors such as Laban, Freire, and Vygotsky, its practice contributes to stimulating creativity, autonomy, and sensitive learning, allowing students to explore their emotions, perceptions, memories, and identities through movement. It is particularly relevant in the context of inclusive education, where the body is seen as a language accessible to different forms of expression and communication.

In the arts, dance therapy connects with practices of contemporary dance, Brazilian dances, bodily performances, and artistic creation processes. Many professionals move between the worlds of clinical practice and art, developing hybrid methodologies that integrate improvisation, body awareness, somatic research, and aesthetic experimentation. This interface strengthens the understanding of dance as a sensitive experience and as a tool for personal and social transformation.

Thus, dance therapy in Brazil is characterized by its diversity of approaches, its adaptation to local realities, and the plurality of spaces where it develops. The practice has proven powerful in promoting care, human development, and inclusion, articulating body, art, and health in an integrated manner.

DANCE SCHOOLS AND COMMUNITY SPACES AS THERAPEUTIC ENVIRONMENTS

Dance schools and community spaces have become important therapeutic environments, especially in urban contexts where accelerated rhythms, social fragmentation, and increasing emotional disorders demand spaces for care, expression, and coexistence. Dance, as a universal bodily language, enables experiences that go beyond technical learning, fostering socialization, well-being, and the strengthening of affective and community bonds.

In the process of socialization, dance acts as a practice that encourages encounter, cooperation, and recognition of the other. Dance groups stimulate a sense of belonging, expand non-verbal communication, and promote the construction of support networks—fundamental aspects for emotional health. As studies on community bodily practices point out, shared movement stimulates empathy, expression of feelings, and group trust, making dance a catalyst for human relationships (Le Breton, 2011; Laban, 1978).

In terms of well-being, dance contributes to psychophysical balance by integrating body, emotion, and sensations. Rhythmic activity improves mood, reduces muscular tension, and aids emotional self-regulation, being recognized by psychologists and therapists as a complementary resource for promoting quality of life. The playful and creative nature of dance also enhances self-esteem, a sense of vitality, and contact with one's own corporeality.

In this context, schools such as Planet, located in Brasília, stand out for integrating technical dance training with practices that value human development. Planet has become a regional reference by offering diverse modalities—such as contemporary dance, ballet, jazz, urban dances, and well-being-oriented activities—which may include body awareness workshops, improvisation practices, therapeutic dance classes, or social projects aimed at different age groups. These environments broaden the understanding of dance as a transformative and accessible experience, allowing participants to find, beyond technical learning, a space for self-care, creativity, and emotional expression.

Planet's work also extends to community projects and cultural events, where dance is used as an instrument of inclusion, social integration, and strengthening of collective identities. By promoting gatherings, performances, and activities open to the public, the school reinforces its role as a space for coexistence and expanded health, where art becomes a vehicle for human connection and socio-emotional development.

Thus, dance schools and community spaces, such as Planet, demonstrate that movement can be a powerful path to transform routines, reframe challenges, and promote comprehensive well-being. By offering welcoming and creative environments, these spaces reinforce the idea that dance is more than technique: it is a practice of care, expression, and collective construction of health..

CONCLUSION

The conclusion of this study emphasized the importance of dance therapy as an innovative and holistic approach to promoting physical and emotional health. Throughout the research, it became evident that dance, in its multiple manifestations, serves not only as a means of artistic expression but also as a significant therapeutic resource in diverse social contexts. The analysis of dance therapy practices in non-clinical environments, particularly in dance schools and community centers, revealed that these spaces can be transformative, providing enriching experiences of self-care, socialization, and human development.

The study demonstrated that dance therapy integrates theory and practice, ensuring a dynamic that fosters interaction between body and emotion. This translates into tangible benefits, such as stress reduction, strengthening of social bonds, and promotion of psychological well-being. Dance schools have proven to be relevant venues for this approach, allowing students and participants to access not only technical skills but also a deeper understanding of themselves and their emotions.

Furthermore, the research highlighted that incorporating dance therapy practices into public health and education policies is essential. Even though dance therapy is not formally recognized as an integrative practice, its contributions to collective health are undeniable. By serving various age groups

and populations, dance therapy emerges as an effective strategy for addressing contemporary emotional challenges, especially in a world increasingly marked by stress and loneliness.

Finally, it was concluded that strengthening dance therapy practices should be a priority for health professionals, educators, and public managers. Promoting comprehensive well-being through dance is a proposal that not only enriches individual experience but also fosters more cohesive and healthier communities. The continuation of studies and the optimization of methodologies that integrate art, health, and education are fundamental for dance therapy to fulfill its role in creating meaningful spaces for care and expression, demonstrating that movement is, indeed, a powerful agent of personal and social transformation.

REFERENCES

1. ADTA – American Dance Therapy Association. Definition and overview. ADTA, 2022.

2. Brasil. Ministério da Saúde. Política Nacional de Práticas Integrativas e Complementares no SUS [National Policy on Integrative and Complementary Practices in SUS]. Brasília, 2017.

3. Chairlin, S.; Schmais, C. The Chace Approach to Dance Therapy. American Journal of Dance Therapy, 1993.

4. Laban, R. Domínio do movimento [Mastery of Movement]. São Paulo: Summus, 1978.

5. Laban, R. The Mastery of Movement. Boston: Plays Inc., 1978.

6. Le Breton, D. Antropologia do corpo e modernidade [Anthropology of the Body and Modernity]. Petrópolis: Vozes, 2011.

7. Levy, F. J. Dance Movement Therapy: A Healing Art. Reston: AAHPERD, 1988.

8. Martins, R.; Saraiva, M. C. Dança e saúde no Brasil: perspectivas contemporâneas [Dance and Health in Brazil: Contemporary Perspectives]. Revista Brasileira de Estudos da Presença, 2019.

9. Merleau-Ponty, M. Fenomenologia da percepção [Phenomenology of Perception]. São Paulo: Martins Fontes, 1999.

10. Santos, E.; Campelo, A. Dança, educação e subjetividade: práticas corporais na escola [Dance, Education and Subjectivity: Body Practices in School]. Educação & Realidade, 2020.

11. Santos, E.; Campelo, A. Dança e bem-estar em espaços educativos [Dance and Well-being in Educational Spaces]. Educação & Realidade, 2020.

12. Silva, M.; Rocha, P. Dança, comunidade e saúde: práticas coletivas no contexto urbano [Dance, Community and Health: Collective Practices in Urban Context]. Revista Corporeidade e Movimento, 2020.

13. Whitehouse, M. Creative Expression in Physical Movement is Language without Words. In: Chace, M. et al. Foundations of Dance/Movement Therapy. 1979.

ISBN: 978-65-83849-24-3

INTEGRATED ACTION FOR CANCER EDUCATION, PREVENTION, AND SCREENING: PINK OCTOBER

https://doi.org/10.63330/aurumpub.021-008

Ingred da Silva Noleto[1], Geovana Lissa Marques Alencar Silverio[2], Gabrielle de Almeida Cavalcante[3], Letícia Glória Alves[4], Márcia Ferreira Sales[5], Gerismar Cardoso Silva[6] and Sara Janai Corado Lopes[7]

ABSTRACT

Breast cancer is a major public health problem among Brazilian women, responsible for high morbidity and mortality rates. Early diagnosis is essential for successful treatment and improved quality of life, and primary health care plays a central role in promoting preventive and educational actions. In this context, the Pink October campaign stands out as a global awareness movement. Objective: To promote educational and preventive actions aimed at raising awareness and early screening for breast and cervical cancer through integrated action between academics, health professionals, and the local community. Methodology: This is a descriptive study based on an experience report from a Pink October campaign in a municipality in Tocantins, conducted by medical students and the Academic League of Gynecology and Obstetrics of Afya Faculdade Porto Nacional (LAGOP). The initiative focused on breast cancer prevention, with lectures, training sessions, and clinical consultations for women in the community. Results: The initiative involved 80 women, with 18 PCCU collections and clinical breast examinations performed. Conclusion: The experience strengthened the bond between students, professionals, and the community, promoting awareness about self-care and early detection of diseases. In addition to expanding access to health services, the initiative contributed to the training of future doctors who are more sensitive

[1] Medical Student
Afya Faculdade Porto Nacional
E-mail: ingrednoleto95@gmail.com
LATTES: http://lattes.cnpq.br/4661199601185766.2
[2] Medical Student
Afya Faculdade Porto Nacional
E-mail: lissaalcrestudos@gmail.com
LATTES: http://lattes.cnpq.br/1359253952572686
[3] Medical Student
Afya Faculdade Porto Nacional
E-mail: almeidacavalcante606@gmail.com
LATTES: http://lattes.cnpq.br/6715439048241972
[4] Medical Student
Afya Faculdade Porto Nacional
E-mail: alvesglorialeticia@gmail.com
LATTES: http://lattes.cnpq.br/5872140939344111
[5] Nurse, Master's Degree, Faculty Member
Afya Faculdade Porto Nacional
E-mail: marcia.sales@afya.com.br
LATTES: https://lattes.cnpq.br/43883977900314091
[6] Pharmacist, Medical Student
Universidade Nacional Ecológica
E-mail: Gerisfarma1@gmail.com
LATTES: http://lattes.cnpq.br/7792420085003148
[7] Nurse, Master's Student, Faculty Member
Afya Faculdade Porto Nacional
LATTES: http://lattes.cnpq.br/3199193467116521

and committed to the reality of the SUS, highlighting the ongoing importance of educational and preventive actions in controlling breast cancer and promoting women's overall health.

Keywords: Primary Care; Women; Screening.

INTRODUCTION

Breast cancer and cervical cancer represent significant public health problems in Brazil, accounting for high morbidity and mortality rates among women. Their epidemiological relevance is evidenced by estimates from the National Cancer Institute (INCA), which annually projects more than 66,000 new cases of breast cancer and approximately 17,000 cases of cervical cancer (Brazil, 2023). Given this scenario, the need for continuous strategies for prevention, screening, and early diagnosis is reinforced, aiming to reduce mortality and strengthen Comprehensive Women's Health Care, especially within Primary Health Care (PHC), the main gateway to the Unified Health System (SUS) (Schuler et al., 2024).

Early diagnosis is one of the determining factors for therapeutic success and improved quality of life for women affected by these neoplasms (Teixeira; Gondinho, 2022). In this context, PHC plays an essential role in implementing educational and preventive actions, promoting self-care and equitable access to health services. Professionals and students in the field assume a leading role in promoting awareness, especially during public campaigns such as Pink October, which mobilizes society around the importance of prevention and early diagnosis (Melo et al., 2021; Barbosa et al., 2024).

The Pink October campaign, consolidated as a global movement, emphasizes clinical breast examination, mammography, and cervical cytology (PCCU) as fundamental screening strategies (Hehn, 2023). Beyond its symbolic character, the movement represents a space for dialogue and health education. In this scenario, university extension stands out as an instrument for articulating teaching, research, and society, enabling the practical application of scientific knowledge and the training of professionals committed to social demands. According to Sá, Monici, and Conceição (2022), extension projects contribute to the technical and human development of students. Academic Leagues, in turn, emerge as privileged spaces for this integration, guided by the principle of inseparability between teaching, research, and extension, offering students opportunities for theoretical-practical learning and community engagement (Botelho et al., 2013; Silva; Flores, 2015).

Considering the importance of screening in PHC and the potential of university extension in social mobilization, this study aims to analyze the experience of an extension activity developed by the Academic League of Gynecology and Obstetrics of Porto Nacional (LAGOP) during the Pink October campaign in a municipality in Tocantins. Guiding Question: What is the contribution and impact of an extension activity in promoting awareness and early screening for breast and cervical cancer, and in strengthening the bond between university and community?

General Objective: To analyze the experience of an extension activity by LAGOP, describing the activities carried out and assessing its contribution to promoting educational and preventive actions. Specific Objectives: Describe awareness and screening activities; Report the methodology and scope of

community mobilization; Discuss the relevance of integrating teaching, research, extension, and community in academic training.

The relevance of this study lies in the need to highlight the active and transformative role of the university in public health. The detailed record of this experience significantly contributes to the literature by demonstrating how an extension activity serves as a powerful vector for health promotion. This work illustrates the practical application of theoretical knowledge about the importance of early diagnosis and the effectiveness of social mobilization in community engagement. Furthermore, by linking theory to practice, the study underscores the invaluable value of experience in Academic Leagues for the human and technical development of future professionals. Thus, this project is justified by its ability to train students aligned with the principles of the Unified Health System (SUS) and deeply committed to women's comprehensive health and societal demands..

METHODOLOGY

This work is configured as an experience report that details and analyzes the planning and execution stages of a university extension activity focused on women's health. The applied methodology integrates the dimensions of teaching, research, and extension, being fundamental for academic training and community impact.

TYPE AND NATURE OF THE STUDY

This experience report is characterized as a descriptive study with a qualitative approach. The objective is to describe in detail the planning process, execution logistics, and activities developed during the health action in a municipality in Tocantins, offering an in-depth view of the students' experience and the impact on the community.

SETTING AND POPULATION (SAMPLE)

The extension activity took place in a primary health care unit in a municipality in the state of Tocantins (TO). The event was planned with an open invitation to the entire community, characterized as a convenience sample of free demand. The total participation was approximately 80 people, with 18 patients attended for cervical cytology (PCCU) collection and breast evaluation.

ORGANIZATION AND PARTNERSHIPS

The activity was organized by fourth-period medical students within the scope of the Interdisciplinary Practices of Extension and Teaching (PIEPE) course, which aims to articulate teaching and extension focused on community health. The Academic League of Gynecology and Obstetrics of

Porto Nacional (LAGOP) was invited to collaborate as a technical partner, assuming an active role in both student training and field execution.

PREPARATION TECHNIQUES AND INSTRUMENTS

Como técnica de preparação e instrumento de garantia de qualidade técnica, a LAGOP promoveu uma capacitação teórica e prática para os acadêmicos. O treinamento foi conduzido por uma médica especialista em Ginecologia e focou na padronização dos procedimentos clínicos.

Training content

During this session, the following were addressed in detail: humanized patient reception, collection of essential data in anamnesis, step-by-step PCCU collection, breast evaluation technique, and correct completion of the cytology request form. The training was crucial for students to act safely and proficiently during the activity.

FLOW AND EXECUTION OF FIELD ACTION

The development of the activity at the site followed a structured care flow to optimize time and service quality. The steps were:

Stages of care

Reception and Welcome of Patients; Recording of Information on the medical history form; Escorting Patients to the procedure room; Performance of Breast Examination and Collection of PCCU by the technical team.

Role of LAGOP in the execution

LAGOP members were responsible for managing the flow, from receiving medical history forms and escorting patients to welcoming them during the procedure and providing direct support in performing the collections, acting under supervision and ensuring the safety and technical quality of the screening process.

EDUCATIONAL AND PEDAGOGICAL STRATEGIES

Educational activities were used as the main technique for disseminating information. These included lectures and interactive dynamics, such as games and quizzes, planned with a clear pedagogical purpose: to promote awareness and prevention of cervical and breast cancer. The educational content

addressed early diagnosis, vaccination (HPV), self-care, and the importance of information dissemination within the community.

METHODOLOGICAL DISCUSSION

The methodology adopted in this report, based on teaching, extension, and care practice, proves highly effective for the proposed objectives. The integration of LAGOP with the PIEPE discipline enabled a virtuous cycle: formal training enhanced students' clinical competence; supervised care practice (PCCU collection) strengthened practical skills in gynecology; and educational activities ensured health information dissemination and positive community impact. This model not only promotes education and prevention in women's health but also fulfills the university's social function, training professionals more committed and fully prepared for SUS demands.

RESULTS AND DISCUSSION

The experience of the extension activity developed by the Academic League of Gynecology and Obstetrics of Porto Nacional (LAGOP) in a municipality in Tocantins generated significant findings in three interconnected spheres: academic training, community adherence to screening, and logistical challenges in public health. Interpreting these results allows for an in-depth analysis of the effectiveness of university extension methodology in the context of women's health.

IMPACT ON ACADEMIC TRAINING AND SKILLS DEVELOPMENT

One of the main findings of the study lies in the enhancement of student learning through direct engagement with the population, reaffirming the potential of extension as an active methodology in the educational process. Field experience enabled students to apply theoretical knowledge concretely, especially regarding PCCU collection, clinical breast examination, anamnesis, and patient reception. Prior training conducted by a specialist was crucial to ensure technical safety and standardization of procedures. This result aligns with the literature, which asserts that clinical skills develop not only through study but through conscious repetition in real scenarios (Lima et al., 2023; Dias et al., 2024).

In addition to technical improvement, the development of humanistic competencies such as empathy, effective communication, and professional demeanor stood out. These attributes are considered essential for a humanized medical practice aligned with the principles of the Unified Health System (SUS) (Berchet; Guanais, 2021; Corrêa et al., 2022), demonstrating that extension acts as a vehicle for the comprehensive training of future health professionals.

EFFECTIVENESS OF SCREENING ACTIONS AND LINKAGE WITH PHC

The role of Primary Health Care (PHC) was evident as the structuring axis of the activity. The integration between the local health unit, students, and the community showed that prevention is strengthened when care is accessible, territorialized, and linked to the population's reality (Berchet; Guanais, 2021).

Community adherence and response

There was good adherence to the event, with approximately 80 participants and 17 PCCU collections performed. This data demonstrates the population's interest and need when service provision is combined with health education (Lima et al., 2023). The model that combined lectures, interactive dynamics, and clinical care reinforces the thesis that symbolic campaigns such as Pink October gain real impact when associated with expanded access to diagnostic procedures, rather than mere abstract awareness (Dias et al., 2024; Lombaldo, 2023).

The challenge of continuity of care

A crucial advancement of this experience was overcoming the common limitation of one-off actions by ensuring a system for returning test results. Thanks to a partnership with a private laboratory, PCCU results were delivered within thirty days, reinforcing continuity of care and facilitating timely referrals in altered cases. This measure is fundamental for effective prevention, reducing the risk of loss to follow-up (Corrêa et al., 2022).

LIMITATIONS AND PERSPECTIVES FOR PERMANENT EXTENSION

Despite positive results, the experience revealed limitations inherent to episodic interventions. The activity had limited reach compared to the population size, indicating that isolated actions, no matter how well planned, do not replace permanent large-scale screening strategies (Dias et al., 2024). Furthermore, a possible selection bias was identified, as participants tend to be women with greater prior interest in their health, leaving out those with less access or risk perception (Corrêa et al., 2022).

Educational and organizational strategies

Educational dynamics proved to be an efficient and well-accepted tool, making content lighter and more applicable (Lombaldo, 2023). To increase reach, it is suggested to include simple printed materials and train community health agents as information multipliers. These measures aim to ensure continuity of health education and strengthen the bond between the community and health services (Berchet; Guanais, 2021).

From an organizational perspective, the experience highlighted the importance of standardizing workflows, defining responsibilities for each stage, and articulating with municipal management. Additionally, there is an opportunity to transform these field actions into applied research, generating data on community perception and screening indicators.

CONCLUSION

The action by LAGOP in a municipality in Tocantins successfully fulfilled the proposed pedagogical, care, and social objectives. The main results demonstrate the effectiveness of the extension methodology and reinforce the essential nature of preventive actions and health promotion for women within Primary Care: Formative Impact: The experience showed that university extension is a key component in medical education, acting as an active methodology that enhances learning, strengthens preventive actions, and allows students to apply theoretical knowledge, especially in PCCU collection, clinical breast examination, and patient reception. Essential attributes such as empathy and professional demeanor stood out; Strengthening Prevention: Performing PCCU collection and clinical breast examinations enabled the screening of possible alterations and strengthened the bond between the health team, medical students, and the local community.

The action corroborates the power of preventive measures in the territory and the impact of campaigns such as Pink October when associated with expanded access to services; Community Empowerment: The relevance of health education through university extension was reinforced as an essential tool for encouraging self-care and female empowerment, contributing significantly to early disease detection; Guarantee of Continuity: A crucial differentiator was the structuring of a system for returning test results in partnership with a laboratory, ensuring continuity of care and facilitating timely referrals, overcoming one of the main limitations of one-off actions. The central contribution of this report is to reinforce that prevention requires continuity, bonding, and shared responsibility, acting as a model that articulates teaching, service, and community with tangible benefits for all parties involved.

The experience, although successful, revealed gaps that guide the prospect of future studies: Long-Term Impact Research: Conduct quantitative studies to measure the long-term impact of these actions on community perception of prevention and screening indicators (coverage rate) before and after the intervention. Development of Educational Tools: Investigate the effectiveness of different educational materials, such as self-care flowcharts and simple apps, to help maintain health education after the extension team leaves. Sustainability Models: Explore partnership and logistics models to transform one-off actions into permanent large-scale screening strategies, including strengthening the training of community health agents as information multipliers. Initiatives of this nature should be continuously

encouraged so that the challenge of transforming a one-time action into permanent impact is overcome, contributing more significantly to Brazilian public health.

REFERENCES

1. Barbosa, N. S. S. et al. Relato de experiência sobre a campanha Outubro Rosa: promoção da conscientização e do autocuidado em uma unidade básica de saúde em área de vulnerabilidade [Experience Report on the Pink October Campaign: Promoting Awareness and Self-Care in a Primary Health Unit in a Vulnerable Area]. Enfermagem: Pesquisas que Transformam a Prática, v. 1, p. 173–176, 2024. Disponível em: https://search.crossref.org/search/works?q=10.37885/241118181&from_ui=yes/. Acesso em: 2 nov. 2025.

2. Berchet, C.; guanais, F. Primary Health Care in Brazil. Paris: OECD, 2021. Disponível em: https://www.oecd.org/content/dam/oecd/en/publications/reports/2021/12/primary-health-care-in-brazil_8ba611b2/120e170e-en.pdf/. Acesso em: 2 nov. 2025.

3. Botelho, N. M.; ferreira, I. G.; souza, L. E. A. Ligas acadêmicas de medicina: artigo de revisão [Academic Medical Leagues: A Review Article]. Rev. para. med., 2013. Disponível em: https://www.researchgate.net/publication/287216091_Ligas_Academicas_de_Medicina_Artigo_de_Revisao. Acesso em: 2 nov. 2025.

4. Braz, M. M. P.; da silva lima, I.; de lima, L. R. Detecção precoce e tratamento eficaz do câncer de colo de útero e mama: um relato de experiência [Early Detection and Effective Treatment of Cervical and Breast Cancer: An Experience Report]. Encontro de Extensão, Docência e Iniciação Científica (EEDIC), v. 20, 2024. Disponível em: https://publicacoes.unicatolicaquixada.edu.br/index.php/eedic/article/view/2057/1937/. Acesso em: 2 nov. 2025.

5. Brasil. Instituto Nacional de Câncer José Alencar Gomes da Silva (INCA). Estimativa 2023: incidência de câncer no Brasil [Estimate 2023: Cancer Incidence in Brazil]. Rio de Janeiro: INCA, 2023. Disponível em: https://www.inca.gov.br/publicacoes/livros/estimativa-2023-incidencia-de-cancer-no-brasil/. Acesso em: 2 nov. 2025.

6. Corrêa, F. M.; migowski, A.; almeida, L. M.; soares, M. A. Cervical cancer screening, treatment and prophylaxis in Brazil: current and future perspectives for cervical cancer elimination. Rio de Janeiro: Instituto Nacional de Câncer, 2022. Disponível em: https://ninho.inca.gov.br/jspui/bitstream/123456789/10342/1/Cervical%20cancer%20screening%2C%20treatment%20and%20prophylaxis%20in%20Brazil%20-%20Current%20and%20future%20perspectives%20for%20cervical%20cancer%20elimination%20-%202022.pdf. Acesso em: 2 nov. 2025.

7. Dias, M. B. K. et al. A cross-sectional study conducted in Brazil and its regions: estimate of the need for procedures of breast cancer early detection and assessment of adequacy in the SUS in 2019. 2024. Disponível em: https://doi.org/10.1590/0102-311XPT139723. Acesso em: 2 nov. 2025.

8. Hehn, C. S. Comunicação pública e seu papel no alerta de detecção precoce do câncer de mama: uma análise do planejamento da campanha "Outubro Rosa" no município de Porto Alegre no ano de 2022 [Public Communication and Its Role in Early Breast Cancer Detection Alert: An Analysis of the Pink October Campaign Planning in Porto Alegre in 2022]. 2023. Disponível em: https://lume.ufrgs.br/bitstream/handle/10183/266746/001178093.pdf?sequence=1&isAllowed=y/. Acesso em: 2 nov. 2025.

9. Herculano, D. et al. Outubro Rosa - um toque de cuidado [Pink October – A Touch of Care]. REUNI Atenas, v. 3, n. 1, 2025. Disponível em: https://revistas.atenas.edu.br/reuni/article/view/548. Acesso em: 2 nov. 2025.

10. Lima, A. O. F. de et al. Cervical cancer prevention strategies in Primary Health Care (PHC). RSD Journal, 2023. Disponível em: https://rsdjournal.org/rsd/article/view/39772. Acesso em: 2 nov. 2025.

11. lombaldo, P. A. B. F. Early detection of breast cancer – integrative review. RSD Journal, 2023. Disponível em: http://dx.doi.org/10.33448/rsd-v12i5.41727. Acesso em: 2 nov. 2025.

12. Melo, F. B. B. et al. Detecção precoce do câncer de mama em Unidades Básicas de Saúde [Early Detection of Breast Cancer in Primary Health Units]. Acta Paulista de Enfermagem, v. 34, p. eAPE02442, 2021. Disponível em: https://www.scielo.br/j/ape/a/b85WmQYK4dbmLFPnT3TwnVs/?format=html&lang=pt. Acesso em: 2 nov. 2025.

13. Sá, M. A. M. de; monici, S. C. B.; conceição, M. M. A importância do projeto de extensão e o impacto que ele tem no processo formativo dos estudantes universitários [The Importance of Extension Projects and Their Impact on University Students' Training Process]. Revista Científica ACERTTE, v. 2, n. 3, p. e2365-e2365, 2022. Disponível em: https://doi.org/10.47820/acertte.v2i3.65. Acesso em: 2 nov. 2025.

14. Schuler, M. F. L. et al. A importância da Atenção Primária na prevenção e detecção precoce do câncer de mama [The Importance of Primary Care in Breast Cancer Prevention and Early Detection]. Brazilian Journal of Implantology and Health Sciences, v. 6, n. 1, p. 544–554, 2024. Disponível em: https://doi.org/10.36557/2674-8169.2024v6n1p544-554. Acesso em: 2 nov. 2025.

15. Silva, S. A. da; flores, O. Ligas acadêmicas no processo de formação dos estudantes [Academic Leagues in the Student Training Process]. Revista Brasileira de Educação Médica, v. 39, p. 410–417, 2015. Disponível em: https://www.scielo.br/j/rbem/a/QQMLpX339cvhMq5R6TsTT9M/?format=pdf&lang=pt. Acesso em: 2 nov. 2025.

16. Teixeira, G. A. T.; gondinho, B. V. C. Análise dos benefícios ao SUS e seus usuários do diagnóstico precoce do câncer de colo de útero e câncer de mama [Analysis of Benefits to SUS and Its Users from Early Diagnosis of Cervical and Breast Cancer]. Universidade de São Paulo, São Paulo, 2022. Disponível em: https://ecopolsaude.com.br/wp-content/uploads/2025/05/11-Glauce-DEFESA.pdf. Acesso em: 2 nov. 2025.

ISBN: 978-65-83849-24-3

Aurum EDITORA

CHAPTER 9

THE IMPACT OF LATE SCREENING FOR FEMALE NEOPLASMS IN PRIMARY HEALTH CARE (APS): ANALYSIS BASED ON THE MINISTRY OF HEALTH PROTOCOL

https://doi.org/10.63330/aurumpub.021-009

Anna Beatriz de Oliveira Sousa[1], Daionny Diniz de França Vasconcelos[2], Glenda Paula Silva Borges[3], Beto Cherles Coral Rodrigues[4], Katelaine Maria Mantuam[5], Ana Cristina Magalhães Mesquita[6], Terciane Soares de Oliveira[7], Bruna Angélica Strunkis[8], Solange Pereira Glória[9] and Jairo Bastidas[10]

ABSTRACT

Timely screening for female neoplasms is one of the essential pillars of Primary Health Care (APS), particularly in view of the high burden of morbidity and mortality associated with cervical cancer and breast cancer in Brazil. Despite the existence of consolidated guidelines issued by the Ministry of Health, which establish clear criteria for periodicity, risk groups, and clinical approach, a significant gap remains between formal recommendations and the reality of care delivery. Late screening often results in diagnoses at advanced stages, greater therapeutic complexity, high costs, and unfavorable outcomes, highlighting the need for continuous improvement in health prevention and surveillance strategies. Among the factors contributing to the late performance of examinations, structural barriers stand out, such as insufficient human resources, care demands that overload teams, weaknesses in scheduling appointments and tests, and technological limitations related to the registration and follow-up of users. Added to this are sociocultural aspects that directly influence the pursuit of care, including low risk perception, fear of diagnosis, misinformation, gender inequalities, and socioeconomic vulnerabilities that restrict ongoing and organized access to services. Inadequate coordination among different points of the network also undermines the diagnostic flow, prolonging the time between screening, case confirmation, and the start of treatment. From a clinical and epidemiological standpoint, the impact of late screening manifests in increased incidence of advanced cases, reduced cure rates, and a higher occurrence of physical and psychosocial sequelae. In APS, this scenario reinforces the importance of proactive team performance, strengthening health education actions, active outreach to women who are overdue, qualified listening, and effective integration with medium- and high-complexity services. The consistent

[1] Undergraduate Medicine student - Uningá
E-mail: annabeatrizmedicina05@gmail.com
[2] Undergraduate Medicine student
E-mail: daionnydiniz@hotmail
[3] Graduate in Biomedicine
E-mail: glendaborges.biomedica@gmail.com
[4] Specialist in Small Animal Veterinary Oncology - Faculdade Unyleya
E-mail: beto.rodrigues@ufrpe.br
[5] Graduate in Biomedicine – UNIBF
E-mail: katelainemari@gmail.com
[6] Master's in Health Promotion – Federal University of Minas Gerais UFMG
E-mail: anacmesquita@yahoo.com.br
[7] Postgraduate student in Hospital Pharmacy and Oncology Care - ICTQ
E-mail: tercyanesoa@gmail.com
[8] Graduate in Pharmacy and Biochemistry - Facimed
E-mail: Bruna.Strunkis_Bioquimica@hotmail.com
[9] Postgraduate in Biology Teaching
E-mail: solangegloria@seduc.to.gov.br
[10] Universidade São Francisco
E-mail: jairobg@gmail.com

adoption of Ministry of Health recommendations—especially regarding the periodicity of the cytopathological examination and the performance of mammography for the indicated age groups—proves crucial to reverse this picture. In summary, addressing the late screening of female neoplasms requires coordinated actions sensitive to territorial vulnerabilities and a continuous institutional commitment to comprehensive, resolutive, and equitable care.

Keywords: Primary Health Care; Cervical cancer; Breast cancer; Early diagnosis.

INTRODUCTION

Screening for female neoplasms, particularly breast cancer and cervical cancer, constitutes one of the structuring axes of Primary Health Care (APS), given its capacity to reduce morbidity and mortality and expand the effectiveness of care networks. Recent literature reinforces that early detection remains one of the most efficient strategies to improve prognoses, minimize higher-complexity interventions, and reduce care costs. Epidemiological studies, such as those presented by Bray et al. (2024) in the global report of the International Agency for Research on Cancer (IARC), demonstrate that countries with consistent population screening programs show a significant reduction in mortality from breast cancer and from precursor lesions of cervical cancer. These findings speak directly to the Brazilian context, where structural inequalities still limit the regularity and effectiveness of screening.

In the specific field of women's health, authors such as Mendes (2022) and Boffa and collaborators (2023) emphasize that delays in performing preventive examinations are associated with socioeconomic barriers, territorial fragilities, low health literacy, and failures in the longitudinal follow-up of users. APS, as the preferred gateway to the Unified Health System (SUS), plays a strategic role in articulating actions of prevention, health education, and continuous surveillance. Nevertheless, as highlighted by Silva and Tomasi (2023) in their analyses of APS performance in Brazil, a gap still exists between official guidelines and care practices, hindering the realization of timely, continuous, and equitable screening.

The Ministry of Health has been updating guidelines and protocols to strengthen early detection, including the periodicity of the cytopathological examination, the indication of mammography, and the systematization of follow-up for women who are overdue. However, implementation of these recommendations faces challenges related to the organization of work processes, availability of inputs, integration of surveillance with care, and the responsiveness of teams in vulnerable territories. Given this scenario, it becomes essential to critically analyze how late screening has impacted women's health and which structural aspects of APS contribute to this outcome. Thus, the general objective of this work is to assess the impact of late screening for female neoplasms in APS, taking as reference the guidelines recommended by the current Ministry of Health protocol.

METHODOLOGY

This study adopted a descriptive and analytical design, with a qualitative approach and documentary character, aiming to examine in depth the impact of late screening for female neoplasms in Primary Health Care (APS), in light of current Ministry of Health guidelines. Such an approach makes it possible to understand, beyond normative recommendations, the structural, organizational, and sociocultural factors that influence the effectiveness of screening.

Types of Data Collection:

Data collection was developed along two main lines:

1. **Institutional documentary collection:** This included guidelines, manuals, clinical protocols, technical notes, ordinances, and official reports produced by the Ministry of Health and the National Cancer Institute (INCA) between 2018 and 2024. This stage focused on examining criteria, guidance, and epidemiological foundations advocated for screening for breast cancer and cervical cancer.
2. **Scientific bibliographic collection:** This involved a systematized search in the SciELO, PubMed, Web of Science, and Scopus databases, using controlled descriptors and keywords related to the topic, such as "female neoplasms," "traceability," "early detection," "APS," and "public health policies." Priority was given to studies with robust methodology, systematic reviews, national epidemiological analyses, and publications discussing barriers and facilitators of screening in the SUS context.

All selected materials were organized in structured spreadsheets containing information on document type, year, objectives, main findings, and relevance to the thematic axis under analysis.

Inclusion Criteria:

Documents and studies that met the following criteria were included:

1. Publication between 2018 and 2024;
2. Direct approach to screening for breast cancer and/or cervical cancer;
3. Explicit relationship with APS or care processes in public health systems;
4. Full texts available in their entirety;
5. Studies conducted in Brazil or in countries with comparable organization of health systems.

Exclusion Criteria:

The following were excluded:

1. Opinion articles without empirical or documentary basis;
2. Studies focused exclusively on screening in high-complexity services;
3. Experimental research not related to the care or organizational context;
4. Outdated documents, prior to 2018;
5. Duplicate publications or those with low methodological consistency.

Analytical Procedures:

After collection, the material was submitted to thematic analysis according to Braun and Clarke, allowing identification of patterns, contradictions, and gaps between the national protocol and the daily practice of APS. Source triangulation and interpretive coherence were adopted to ensure robustness of the analysis.

This methodology made it possible to understand, in an integrated manner, how the Ministry of Health guidelines are operationalized and which factors contribute to late screening, supporting the discussions presented in the results.

RESULTS AND DISCUSSION

The integrated analysis of official documents and the scientific literature revealed consistent patterns that reinforce the relevance of timely screening for female neoplasms and highlight persistent structural weaknesses in Primary Health Care (APS). The results indicate that the distance between normative guidelines and care practice remains one of the main determinants of late screening in Brazil.

STRUCTURAL AND ORGANIZATIONAL BARRIERS

The findings show that weaknesses in the work process, scarcity of human resources, and the absence of consolidated information systems hinder active outreach, registration, and longitudinal follow-up of users. In many municipalities, the fragmented care flow prevents women who are overdue from being identified and reinserted into preventive care.

Table 1. Organizational barriers associated with late screening

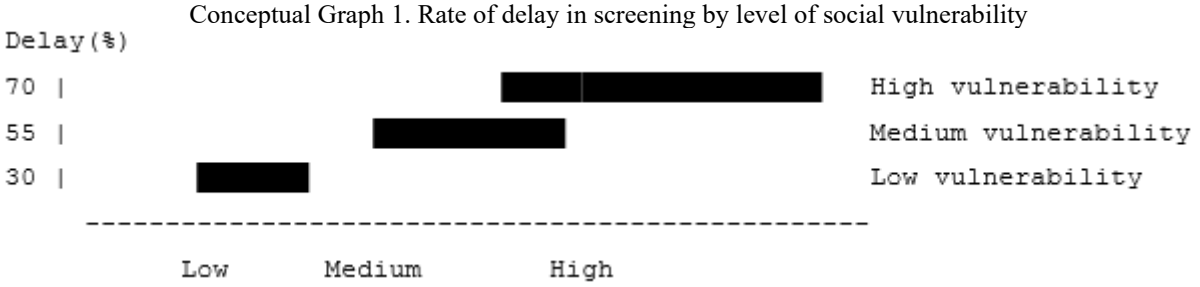
Category	Identified Evidence	Impacts on APS
Human Resources	Reduced teams; high turnover	Reduced supply of preventive appointments
Information Systems	Incomplete medical records; absence of alerts	Difficulty identifying women who are overdue
Care Processes	Lack of internal protocols; low integration with surveillance	Delays in follow-up and failures in return
Infrastructure	Limitations for cytopathological collection and scheduling of mammograms	Delays in access to diagnosis

The data reveal that these elements combine and amplify risks, reflecting an APS which, although guided by robust guidelines, faces operational limitations in fully carrying out screening.

SOCIAL AND TERRITORIAL INEQUALITIES

Socioeconomic inequalities remain critical determinants of access to preventive examinations. Territories with greater vulnerability consistently show lower coverage rates and a higher proportion of examinations outside the recommended periodicity.

Conceptual Graph 1. Rate of delay in screening by level of social vulnerability



This pattern reinforces that equity remains a central challenge, as the risk of late diagnosis is clearly increased among populations exposed to socioeconomic barriers, low education, domestic workload, and mobility difficulties.

CLINICAL IMPACTS OF LATE SCREENING

The review revealed that cervical cancer is most sensitive to delays in screening. In the analyzed studies, municipalities with low coverage of the cytopathological examination exhibited a higher proportion of lesions at advanced stages, requiring more invasive procedures and increasing the risk of avoidable mortality.

Table 2. Clinical consequences of late screening

Clinical Aspect	Cervical Cancer	Breast Cancer
Stage at Diagnosis	Higher proportion of CIN III and invasive cancer	Larger tumors and greater lymph node involvement
Necessary Interventions	Radical surgeries; radiotherapy	Extended surgery; chemo/neoadjuvant therapy
Prognosis	Higher risk of mortality	Reduced chances of cure
Impact on SUS	Increased costs	Longer hospital stays and prolonged therapies

These data confirm the central premise of national guidelines: APS is decisive for ensuring favorable outcomes, provided it can operationalize preventive actions systematically.

INTEGRATED DISCUSSION OF FINDINGS

Comparison between official documents and the literature shows that the problem is not the lack of recommendations but the difficulty of implementing them regularly and with quality. Where there are structured teams, efficient information systems, and integration between surveillance and care, better indicators of early detection are observed. However, in the most vulnerable regions, challenges persist that reinforce inequalities and perpetuate late screening.

Thus, the results indicate that addressing the problem requires structuring strategies: expanding teams, ongoing qualification, strengthening information systems, investing in active surveillance, and regionalized integration of the care network.

CONCLUSION

The findings of this study show that late screening for female neoplasms remains a significant challenge for Primary Health Care (APS), despite the existence of solid and updated protocols established by the Ministry of Health. The integrated analysis of institutional documents and recent literature demonstrated that the main weaknesses are not concentrated in technical recommendations but in the capacity to execute these guidelines in daily service routines.

Organizational barriers, insufficient human resources, weak information systems, and fragmentation of care processes directly compromise the regular performance of cytopathology and mammography, increasing the risk of diagnoses at advanced stages. In parallel, territorial and socioeconomic inequalities reinforce a persistent pattern of inequity, in which women living in more vulnerable areas show lower adherence to preventive examinations and a higher proportion of late cases.

From the clinical standpoint, late screening is associated with more invasive interventions, higher morbidity and mortality rates, and increased care costs, negatively impacting both users and the public health system. Conversely, the results also show that when the guidelines are applied systematically and in an articulated manner, APS can achieve significant performance in early detection, reducing risks and ensuring better quality of life for women.

Thus, it is concluded that overcoming late screening requires continuous investment in team structuring, strengthening of health surveillance processes, expanded qualified use of information systems, effective integration among levels of care, and territorially sensitive strategies tailored to local inequalities. Strengthening APS, aligned with Ministry of Health recommendations, constitutes the most consistent path to expand equity, optimize clinical outcomes, and consolidate a more resolutive, welcoming, and efficient preventive care model.

REFERENCES

1. Damasceno, H. C.; Silva, C. V. S. da; Oliveira, O. P. de; Cavalcante, R. L.; Granato, R. R.; Silva, E. P. S. da; Briana, J. de O.; Ferro, D. B.; Monteiro, J. R. S.; Pinheiro, M. da C. N. Desempenho e qualidade do rastreamento de câncer cervical [Performance and Quality of Cervical Cancer Screening]. Revista Eletrônica Acervo Saúde, v. 25, 2024.

2. Instituto Nacional de Câncer (INCA). Estimativa 2023 – incidência de câncer no Brasil [Estimate 2023 – Cancer Incidence in Brazil]. Rio de Janeiro: INCA, 2023.

3. Instituto Nacional de Câncer (INCA). Dados e números sobre câncer do colo do útero [Data and Numbers on Cervical Cancer]. Rio de Janeiro: INCA, 2023.

4. Instituto Nacional de Câncer (INCA). Estatísticas de câncer [Cancer Statistics]. Disponível em: portal do INCA, seção "Números de câncer". Accessed on: 2023.

5. Brasil. Ministério da Saúde. Secretaria de Vigilância em Saúde. Saúde da mulher brasileira: uma perspectiva integrada entre vigilância e atenção à saúde [Brazilian Women's Health: An Integrated Perspective Between Surveillance and Health Care]. Boletim Especial, 2023.

6. Brasil. Ministério da Saúde. Diretrizes brasileiras para o rastreamento do câncer do colo do útero: Parte I – rastreamento organizado utilizando testes moleculares para detecção de DNA-HPV oncogênico [Brazilian Guidelines for Cervical Cancer Screening: Part I – Organized Screening Using Molecular Tests for Detection of Oncogenic HPV DNA]. Brasília, 2024.

ISBN: 978-65-83849-24-3

RISKS OF DISINFORMATION GENERATED BY AI AND MITIGATION STRATEGIES

https://doi.org/10.63330/aurumpub.021-010

Rodrigo Thomé de Moura[1]

ABSTRACT

This study analyzed the risks of disinformation generated by Artificial Intelligence and presented mitigation strategies capable of reducing its social, political, and institutional impacts. The research aimed to investigate how AI technologies, especially generative models, have expanded the production and circulation of false, misleading, and manipulated content, as well as to assess the consequences of this phenomenon for public trust, democracy, science, and national security. The methodology adopted was bibliographic and qualitative, based on a review of scientific articles, institutional reports, and specialized works discussing Artificial Intelligence, digital disinformation, and informational integrity. The results showed that generative AI enabled the creation of synthetic texts, images, videos, and audio at high speed and scale, making disinformation more sophisticated and harder to detect. It was observed that the increasing realism of deepfakes, voice cloning, and automation through bot networks significantly enhanced the ability to manipulate public perceptions, favoring coordinated campaigns and interference in democratic processes. The analysis also identified that this scenario contributed to the erosion of trust in institutions, the discrediting of scientific evidence, and vulnerabilities in sensitive areas such as public health and national security. The study concluded that mitigating these risks depends on combining technical, political, and educational strategies, including tools for detecting synthetic media, regulations for algorithmic transparency, digital governance policies, and media literacy programs capable of strengthening citizens' critical capacity in the contemporary informational environment.

Keywords: Artificial Intelligence; Disinformation; Deepfakes; Informational security; Mitigation.

[1] Postgraduate in Dance Therapy
Prisma
E-mail: rodrigofsw@gmail.com

INTRODUCTION

The rapid expansion of Artificial Intelligence (AI), especially in its generative applications, has profoundly transformed the contemporary informational landscape, creating new technological possibilities while also triggering significant risks for information circulation and social stability. The advancement of models capable of producing synthetic texts, images, videos, and audio with a high degree of realism has inaugurated a period in which the boundaries between truth and falsification have become increasingly difficult to identify. Authors such as Goodfellow et al. (2016), Wardle and Derakhshan (2017), and Zuboff (2019) have discussed how this phenomenon alters communication dynamics, influences public opinion, and exposes society to new forms of manipulation. In this context, understanding the relationship between AI and disinformation becomes essential to assess its impacts and devise strategies that preserve informational integrity.

This study aimed to analyze the risks of disinformation generated by Artificial Intelligence technologies and discuss mitigation strategies capable of reducing their social, political, and institutional effects. Specifically, it sought to: understand the foundations of generative AI; examine the functioning of digital disinformation and its circulation ecosystem; investigate how AI enhances the creation and dissemination of false content; assess the social and political impacts resulting from this process; and present possible approaches to address the problem. The hypothesis guiding the research considered that AI, despite its benefits, substantially intensifies the reach and realism of disinformation, contributing to the erosion of public trust, democratic manipulation, and vulnerabilities in areas such as health, science, and national security.

The justification for this study lies in the central role that information plays in contemporary societies. In an environment marked by hyperconnectivity, rapid communication flows, and growing dependence on digital platforms, disinformation is not merely a technical problem but a structural phenomenon that threatens democratic processes, public health policies, institutional stability, and social relations. The advancement of generative AI intensifies this scenario, requiring critical and multidisciplinary analyses of its risks and ethical implications.

To develop this investigation, the work was structured into four main parts. After this introduction, the methodology section describes the adopted approach, based on bibliographic research and a qualitative perspective. Next, the development is organized into four subsections: the first presents the fundamental concepts of Generative Artificial Intelligence; the second discusses the different types of digital disinformation and their dynamics on platforms; the third analyzes AI as a vector of disinformation, highlighting scalability, realism, and automation; and the fourth examines the social and political impacts of this phenomenon. Finally, the conclusion revisits the main findings, reaffirms the relevance of the topic, and points to the need for integrated policies and mitigation strategies.

Thus, this research seeks to contribute to the contemporary debate on informational challenges in the age of Artificial Intelligence, offering a broad and critical understanding of the risks involved and reinforcing the importance of ethical, technological, and educational responses that ensure the preservation of truth and social trust.

METHODOLOGY

This research was developed through a qualitative approach and was essentially bibliographic, grounded in the analysis of books, scientific articles, institutional reports, and specialized documents discussing Artificial Intelligence, digital disinformation, and informational security. The choice of this methodology was justified by the conceptual and interpretative nature of the topic, which requires a broad understanding of recent technological transformations and their social and political impacts. Thus, the investigation sought to gather and interpret contributions from authors such as Goodfellow, Wardle, Derakhshan, Zuboff, Floridi, Chesney, and Citron, among other researchers prominent in the contemporary debate on algorithms, synthetic media, and informational integrity.

The methodological path consisted of four main stages. The first involved a systematic review of national and international literature to identify relevant concepts, definitions, and theoretical foundations on generative AI, disinformation ecosystems, and sociopolitical impacts of informational manipulation. Next, case studies, research organization reports, and reference documents produced by entities such as the Council of Europe were selected, addressing phenomena such as deepfakes, coordinated campaigns, and digital interference in democratic processes. The third stage focused on critical analysis of this material, seeking to relate theoretical findings to observed societal transformations, especially regarding the advancement of generative models, the circulation of misleading content, and algorithmic mechanisms that amplify disinformation.

Finally, the results obtained were thematically organized in the development sections, enabling an integrated discussion between technical foundations and social impacts. This methodological structure allowed for a comprehensive understanding of the phenomenon, articulating technological, sociological, and political perspectives, and providing insights for reflection on mitigation strategies that can help address the risks associated with Artificial Intelligence. Thus, the adopted methodology not only theoretically supported the study but also enabled the construction of a consistent, critical analysis aligned with contemporary needs for protecting informational integrity.

DEVELOPMENT

GENERATIVE ARTIFICIAL INTELLIGENCE

Generative Artificial Intelligence has become one of the most innovative and transformative fields in contemporary technology, characterized by its ability to create new and original content based on learning from large volumes of data. Conceptually, it refers to systems capable of generating texts, images, sounds, videos, and other media formats without these contents being previously stored, but rather produced from patterns learned during training. According to Goodfellow et al. (2016), this type of AI relies on probabilistic models capable of understanding complex structures of language and human perception, reproducing them autonomously and in a surprisingly natural way. This feature positions generative AI as a milestone in the history of computing, expanding its use in education, healthcare, design, communication, and entertainment, while also opening fundamental discussions on ethics and responsibility.

Within this category, large-scale language models, known as LLMs (Large Language Models), have become the most popular. They are capable of generating coherent texts, translating content, answering questions, producing summaries, and even simulating specific writing styles. These models, such as GPT, Gemini, and LLaMA, were trained on billions of words, developing the ability to predict the next word in a sequence and thus construct complete narratives. As Kaplan et al. (2020) point out, the larger the volume of data and parameters in a model, the greater its capacity to generate sophisticated responses. Similarly, advances have occurred in image and video generation, with models such as DALL·E, Midjourney, and Stable Diffusion, which can create realistic illustrations, synthetic photographs, and complex scenes based on textual descriptions. These tools have expanded digital creativity, allowing individuals without technical training to produce content previously restricted to highly specialized professionals.

Beyond texts and images, generative AI has also revolutionized audiovisual media through voice synthesis and video manipulation. Voice cloning technologies allow for the replication of any person's tone and timbre with high fidelity, generating entire speeches that appear authentic. Likewise, deepfakes—videos manipulated by deep neural networks—have gained notoriety for their ability to replace faces, synchronize speech, and alter expressions with extreme realism. Studies such as those by Chesney and Citron (2019) highlight that deepfakes represent one of the most concerning forms of synthetic content due to their potential to disseminate disinformation, compromise reputations, manipulate political processes, and create false visual evidence. The sophistication of these methods demonstrates how generative AI can both expand creative tools and generate significant risks for informational integrity and public trust.

In this scenario, it is essential to understand that Generative Artificial Intelligence is not merely a technical advancement but a cultural, social, and ethical phenomenon. As synthetic content production becomes indistinguishable from human production, issues related to authenticity, authorship, privacy, and truth gain centrality in contemporary debate. Thus, studying its basic concepts, models, and applications—including potentially harmful ones—is fundamental to ensuring its use occurs responsibly, transparently, and in alignment with the ethical principles governing digital society.

DIGITAL DISINFORMATION

Digital disinformation has become one of the most urgent problems in contemporary society, intensified by the speed and scale of interactions mediated by digital technologies. In the online environment, disinformation takes different forms, each with specific characteristics and varying degrees of intentionality. So-called fake news are entirely false content deliberately produced to deceive, manipulate, or generate repercussion. There are also manipulated contents, which are based on partially true facts but altered or taken out of context to induce misleading interpretations. Additionally, misleading information—known as misinformation—is shared without explicit intent to cause harm but still contributes to the circulation of false or distorted narratives. Wardle and Derakhshan (2017) classify these phenomena within a spectrum ranging from unintentional error to strategic manipulation, emphasizing that each category requires specific forms of identification and counteraction.

This type of content thrives in a digital ecosystem marked by hyperconnectivity, viral logic, and fragmentation of information sources. On social networks, disinformation circulates rapidly because it finds fertile ground in fast, poorly verified, and emotionally charged interactions. Platforms such as Facebook, X/Twitter, WhatsApp, TikTok, and Instagram function as environments where attractive content has a higher chance of being shared, regardless of its veracity. According to Vosoughi, Roy, and Aral (2018), false news spreads faster than true news precisely because it tends to evoke surprise, indignation, and strong emotional engagement. This means that platform design—structured to maximize attention and engagement—contributes to perpetuating disinformation cycles, often making it difficult for the average user to distinguish between verified information and intentional manipulation.

The role of algorithms and automation in this process is equally central. Recommendation tools based on artificial intelligence select content according to user interest patterns, creating informational bubbles that reinforce pre-existing beliefs and hinder access to diverse perspectives. These algorithms, by privileging engagement, end up amplifying sensationalist or polarizing messages, making disinformation more visible than verifiable content. In parallel, automated systems—such as bots and coordinated accounts—are frequently used to artificially increase the reach of certain content or campaigns. Zannettou et al. (2019) show that organized groups use bot networks to boost false narratives, manipulate public

debates, and influence political processes, turning disinformation into a systemic phenomenon that is difficult to contain.

In this scenario, understanding the complexity of digital disinformation requires analyzing its types, circulation forms, and technological mechanisms that amplify its impact simultaneously. The interaction between users, platforms, and algorithms creates an environment where false or manipulated content achieves high diffusion capacity, with direct effects on public opinion, social trust, and the functioning of democratic institutions. Thus, studying this phenomenon becomes fundamental for developing effective mitigation strategies and public policies that strengthen informational integrity in the digital age.

AI AS A VECTOR OF DISINFORMATION

Artificial Intelligence has established itself as a central vector in the expansion of digital disinformation, mainly due to its ability to produce, replicate, and amplify false content at unprecedented speed and scale. Unlike traditional processes of informational manipulation, which required time, resources, and advanced technical knowledge, AI has made it possible to create falsified texts, images, videos, and audio with just a few commands, democratizing the ability to generate misleading content. Generative tools allow a single individual to produce hundreds or thousands of false messages in minutes, intensifying the volume of circulating disinformation and overloading verification mechanisms. According to Floridi (2021), automation has transformed disinformation into an industrialized phenomenon, capable of spreading rapidly and adapting highly to social media dynamics.

One of the most concerning aspects of this transformation is the growing realism of AI-generated synthetic media. Advanced models produce extremely detailed images, videos that accurately simulate facial expressions, and audio that perfectly imitates the human voice. Deepfakes have become one of the most visible expressions of this capability, enabling the creation of videos in which people appear to say or do things that never happened. As Chesney and Citron (2019) highlight, these contents have the potential to compromise reputations, manipulate political decisions, generate panic in crisis situations, and undermine trust in audiovisual records—a historically central element in validating truth. Although initially detectable by visual flaws, deepfakes have evolved to the point of becoming indistinguishable to the naked eye, significantly increasing their impact.

Beyond direct production of false content, AI amplifies disinformation through automated bots and coordinated campaigns. These systems are programmed to simulate human behavior, participate in debates, boost hashtags, comment on posts, and reinforce specific narratives. Automation allows a small group to create the impression of social consensus or organic engagement around sensitive topics. Zannettou et al. (2019) demonstrate that bot networks have been widely used by political, economic, and

ideological groups to manipulate public perceptions, interfere in electoral debates, and amplify polarizing messages. In many cases, these bots operate in conjunction with generative AI models, creating a highly efficient chain of disinformation production and distribution.

The impacts of this phenomenon are visible in various recent contexts. In electoral processes, AI-fabricated content has been used to defame candidates, manipulate narratives, and influence public opinion, as seen in elections in the United States, India, and several European countries. During health crises, such as the COVID-19 pandemic, synthetic videos and texts were used to spread false information about vaccines, treatments, and preventive measures, contributing to risky behaviors and institutional distrust. In areas such as economics and security, manipulated media have already caused temporary drops in financial markets and spread alarms about nonexistent threats, demonstrating AI's ability to generate concrete and immediate impacts on social life.

Thus, Artificial Intelligence, while representing a significant technological advancement, has also become a powerful catalyst for disinformation. Its ability to produce highly realistic content, operate automatically, and interact with the algorithmic dynamics of digital platforms makes it a central element in understanding contemporary challenges related to informational integrity. Recognizing this role is fundamental for developing mitigation strategies capable of responding to the speed, sophistication, and scale of the problem.

SOCIAL AND POLITICAL IMPACTS

The social and political impacts of disinformation amplified by Artificial Intelligence technologies constitute one of the most serious challenges faced by contemporary societies. The massive circulation of false, manipulated, or misleading content has significantly contributed to the erosion of public trust in institutions, media, and even in the very notion of shared truth. When synthetic information generated by AI becomes indistinguishable from real content, citizens begin to question the credibility of visual evidence, official statements, and verified facts. Zuboff (2019) emphasizes that this scenario of constant uncertainty weakens social cohesion and creates fertile ground for polarizing discourses, making it more difficult to build the minimal consensus necessary for democratic functioning. Thus, trust—the foundation of any structured society—becomes fragile in an environment where the authenticity of information is permanently under suspicion.

AI-supported disinformation also plays a central role in manipulating public opinion and interfering in democratic processes. During electoral periods, falsified content can alter perceptions, shape narratives, and influence the decisions of thousands of voters in short timeframes. Deepfakes, texts fabricated by language models, and coordinated bot networks expand the reach of manipulative campaigns, creating artificial impressions of popular support or spreading false accusations against

political opponents. Wardle and Derakhshan (2017) argue that these mechanisms challenge the fundamental principles of democratic deliberation by distorting public debate, hindering access to reliable information, and strategically manipulating emotions. Digital interference in elections has already been documented in several countries, showing that electoral integrity can be significantly compromised by informational automation technologies.

Beyond the political sphere, the impacts extend to science, public health, and national security. The dissemination of false information about medical treatments, disease diagnosis, or vaccination campaigns—widely observed during the COVID-19 pandemic—has shown how disinformation can generate risky behaviors, reduce adherence to health measures, and aggravate epidemiological crises. In the scientific field, the spread of conspiracy theories and anti-scientific content discredits researchers, hinders evidence-based policies, and reduces the population's ability to differentiate validated knowledge from speculation. In national security, deepfakes and audiovisual manipulations can be used to provoke instability, simulate attacks, create false statements by authorities, or generate collective panic. Chesney and Citron (2019) warn that the sophistication of AI-produced falsifications may render the distinction between real and fabricated threats unfeasible, complicating the rapid response of institutions responsible for social and state protection.

Given this scenario, it becomes evident that AI-enhanced disinformation is not merely a technical problem but a social and political phenomenon of great magnitude. Its effects permeate institutions, decision-making processes, health systems, and social relations, compromising fundamental pillars of democratic coexistence. Understanding these impacts is an essential step toward formulating effective policies for mitigation, strengthening the population's digital literacy, and ensuring that emerging technologies are used ethically and responsibly..

CONCLUSION

This study made it possible to understand that Artificial Intelligence, especially in its generative applications, has played a decisive role in transforming the contemporary informational ecosystem. The ability of these technologies to produce synthetic texts, images, videos, and audio with a high degree of realism has profoundly altered the dynamics of information circulation, expanding the potential for creating and disseminating false, manipulated, or misleading content. The analysis revealed that AI not only accelerated these processes but also made them more complex, efficient, and difficult to detect, shaping a disinformation scenario more powerful and sophisticated than any previously observed.

The results indicated that disinformation generated or amplified by AI directly contributed to the erosion of public trust—a phenomenon that affects democratic institutions, communication systems, scientific practices, and social relations. The growing presence of deepfakes, synthetic speeches,

manipulated images, and automated campaigns has made it harder to distinguish between true and false content, increasing the sense of uncertainty and informational vulnerability. Furthermore, it was highlighted that these technologies facilitated the manipulation of public opinion and political interference, creating conditions for coordinated campaigns that significantly affect electoral processes, governmental agendas, and public debates. It was also evident that AI-supported disinformation caused harm to science, health, and national security, especially in crisis contexts such as pandemics and geopolitical instabilities.

Given this scenario, the study demonstrated that the risks associated with AI do not reside solely in its technical capacity but in the way these technologies are incorporated into social and political dynamics. Thus, mitigating these risks depends on integrated and multidimensional actions. The strategies analyzed indicated the need to combine technical solutions—such as deepfake detection tools, synthetic content labeling, and authentication systems—with regulatory policies that establish algorithmic transparency, platform accountability, and governance mechanisms that protect informational integrity. Likewise, the importance of media education was emphasized as a fundamental strategy to strengthen citizens' critical capacity, enabling them to recognize signs of manipulation and develop greater autonomy when faced with misleading content.

It is concluded, therefore, that addressing AI-generated disinformation requires a joint effort among governments, researchers, technology companies, educational institutions, and civil society. Only through such cooperation will it be possible to ensure that Artificial Intelligence is employed ethically, responsibly, and in alignment with democratic values, preserving social trust and informational security in an increasingly complex and challenging digital context..

REFERENCES

1. Chesney, Robert; Citron, Danielle. Deep fakes: A looming challenge for privacy, democracy, and national security. California Law Review, v. 107, p. 1753–1819, 2019. Available at: https://www.californialawreview.org/print/deep-fakes-a-looming-challenge-for-privacy-democracy-and-national-security/. Accessed on: 14 Nov. 2025.

2. Floridi, Luciano. The Ethics of Artificial Intelligence. Oxford: Oxford University Press, 2021.

3. Goodfellow, Ian; Bengio, Yoshua; Courville, Aaron. Deep Learning. Cambridge: MIT Press, 2016.

4. Kaplan, Jared et al. Scaling laws for neural language models. arXiv, 2020. Available at: https://arxiv.org/abs/2001.08361. Accessed on: 14 Nov. 2025.

5. Vosoughi, Soroush; Roy, Deb; Aral, Sinan. The spread of true and false news online. Science, v. 359, n. 6380, p. 1146–1151, 2018. Available at: https://www.science.org/doi/10.1126/science.aap9559. Accessed on: 14 Nov. 2025.

6. Wardle, Claire; Derakhshan, Hossein. Information Disorder: Toward an Interdisciplinary Framework. Strasbourg: Council of Europe, 2017. Available at: https://firstdraftnews.org/wp-content/uploads/2017/11/PREMS-162317-GBR-2018-Report-de%CC%81sinformation-1.pdf. Accessed on: 14 Nov. 2025.

7. Zannettou, Savvas et al. Disinformation warfare: Understanding state-sponsored trolls on Twitter and their influence on the web. In: Companion Proceedings of the World Wide Web Conference (WWW), 2019. Available at: https://arxiv.org/pdf/1801.09288. Accessed on: 14 Nov. 2025.

8. Zuboff, Shoshana. The Age of Surveillance Capitalism: The Fight for a Human Future at the New Frontier of Power. New York: PublicAffairs, 2019.

ISBN: 978-65-83849-24-3

Aurum EDITORA

CHAPTER 11

COMPUTER VISION FOR FACIAL RECOGNITION: ADVANCES AND RISKS

https://doi.org/10.63330/aurumpub.021-011

Rodrigo Thomé de Moura[1]

ABSTRACT

This work presents a comprehensive analysis of computer vision applied to facial recognition, highlighting its technical advances and the risks associated with the use of this technology in contemporary contexts. The study aimed to explain the foundations of computer vision, describe the technical functioning of facial recognition algorithms, identify the main advances that have expanded the accuracy and dissemination of these systems, and discuss the ethical and social challenges arising from their growing use. The research was developed through a bibliographic review based on relevant works and studies in the fields of artificial intelligence, computer vision, deep learning, and technological ethics. The methodology made it possible to gather, interpret, and compare different theoretical and technical perspectives on the subject, enabling a solid and critical understanding of the phenomenon analyzed. The results showed that facial recognition has evolved rapidly due to the development of deep neural networks, increased computational capacity, and access to large image datasets. The accuracy of these models has increased significantly, leading to the implementation of the technology in mobile devices, access control systems, digital platforms, and security applications. However, the work identified important risks, such as violations of privacy, misuse of biometric data, mass surveillance, algorithmic biases that more intensely affect minority groups, and vulnerabilities associated with digital forgery techniques. The analysis concluded that, although facial recognition represents a significant advance within artificial intelligence, its use requires regulation, transparency, and responsible practices to prevent social harm and ensure the protection of individual rights. The study highlighted the need to balance technological innovation and ethics, pointing to pathways that favor the safe and conscientious application of this tool.

Keywords: Facial recognition; Computer vision; Artificial Intelligence; Privacy; Ethics.

[1] Postgraduate in Dance Therapy
Prisma
E-mail: rodrigofsw@gmail.com

INTRODUCTION

The rapid evolution of Artificial Intelligence has profoundly transformed the way individuals, institutions, and technological systems interact with the digital world. Among these innovations, computer vision stands out as one of the most dynamic areas, as it allows machines to interpret and process visual information in a manner increasingly similar to human capabilities. Within this field, facial recognition has become one of the most widespread applications, present in smartphones, digital platforms, security systems, and mechanisms for automatic authentication. The specialized literature indicates that this technology, driven mainly by advances in convolutional neural networks and deep learning, has reached levels of accuracy previously considered unattainable (Szeliski, 2022; Goodfellow; Bengio; Courville, 2016). However, this accelerated development also raises ethical, social, and technical concerns that require careful analysis.

Thus, the present work focuses on computer vision applied to facial recognition, with an emphasis on its recent advances and the risks associated with its use. This study starts from the understanding that, although extremely useful for biometric authentication, access control, public security, and personalization of digital resources, the technology brings significant challenges related to privacy, the processing of personal data, and the possibility of misuse. The literature consulted reinforces such concerns, highlighting, for example, the high error rates for women, Black people, and minorities (Buolamwini; Gebru, 2018), the risks of mass surveillance (Lyon, 2018), and the increasing sophistication of digital forgeries and deepfakes (Tolosana et al., 2020).

The general objective of this work is to critically analyze the technical advances of facial recognition and discuss the risks and challenges resulting from its expansion. As specific objectives, it seeks to: explain the fundamental concepts of computer vision and image processing; describe the technical functioning of facial recognition and its main algorithms; present the advances that have made this technology more accurate and accessible; and, finally, analyze its ethical, social, and security risks in light of the current literature. The study starts from the hypothesis that, although facial recognition represents a milestone in the development of artificial intelligence, its indiscriminate use without adequate regulation can generate significant negative impacts, especially regarding privacy and social equity.

The justification for this study lies in the contemporary relevance of the topic. In a context in which cameras, sensors, and algorithmic systems become ubiquitous, understanding the functioning and impacts of this technology is essential so that citizens, professionals, and institutions adopt responsible practices aligned with current legislation. Moreover, in light of the growing integration of facial biometrics in public and private spaces, it is urgent to debate limits, risks, and possibilities, contributing to a safer, fairer, and more conscientious use of these tools.

Finally, this work was developed through bibliographic research based on classic and contemporary authors in the areas of computer vision, deep learning, and ethics in artificial intelligence. Throughout the study, fundamental concepts are presented alongside the technical functioning of the systems, their recent advances, and the ethical and social issues arising from their use, enabling a broad, critical, and well-grounded view of the theme..

METHODOLOGY

The work was developed through bibliographic research with a qualitative approach, grounded in the selection, analysis, and interpretation of books, scientific articles, and technical documents related to computer vision, facial recognition, deep learning, and ethics in artificial intelligence. The choice of this method allowed for a broad and critical understanding of technological evolution, the functioning of algorithms, and the social impacts associated with the growing use of this technology. The bibliographic research was conducted based on classic and contemporary authors in the field, making it possible to build a solid and coherent theoretical framework. The methodological process included identifying relevant publications in academic databases, scientific journals, and specialized books, prioritizing materials that discussed in depth the technical aspects, recent advances, and risks involved in facial recognition. After this selection, the content was analyzed and organized into thematic categories, allowing for the structuring of the topics addressed in the development of the work. This procedure made it possible to compare perspectives, synthesize information, and critically discuss the ethical and technological challenges related to the topic. In this way, the methodology adopted ensured theoretical consistency and contributed to a comprehensive analysis, producing a study aligned with academic standards and the purpose of understanding both the advances and the concerns that permeate the use of computer vision applied to facial recognition.

DEVELOPMENT

COMPUTER VISION: BASIC CONCEPTS

Computer vision is one of the most dynamic fields of Artificial Intelligence, as it seeks to enable machines to interpret, analyze, and understand visual information in a manner similar to humans. Broadly speaking, it can be defined as the set of techniques, algorithms, and computational models capable of extracting, processing, and recognizing patterns in images and videos, assigning meaning to this data to perform specific tasks. According to Szeliski (2022), computer vision is based on the capacity to transform raw visual data into structured representations, enabling automated systems to perform tasks ranging from simple activities, such as detecting edges in an image, to complex operations, such as identifying faces, objects, or actions in motion.

Image processing, in turn, is an essential stage within computer vision. It encompasses mathematical and computational procedures aimed at improving, transforming, or analyzing images, enabling the system to extract relevant information for visual recognition. Among the most common techniques are filtering, segmentation, contour detection, and color transformation—fundamental methods for reducing noise, enhancing details, and separating significant elements of the image for later interpretation. According to Gonzalez and Woods (2019), image processing is the foundation upon which more advanced algorithms are built, functioning as a link between the capture of visual information and the automated understanding performed by AI.

In recent years, the most significant advance in the area has occurred with the development of convolutional neural networks (CNNs) and deep learning. CNNs are models deeply inspired by the organization of the human visual cortex and stand out for their ability to identify complex patterns directly from data, without the need to manually extract visual features. LeCun, Bengio, and Hinton (2015) emphasize that this type of network revolutionized the field of computer vision by processing images hierarchically: in the first layers, simple traits such as edges and textures are identified; in deeper layers, abstract representations arise that describe complete objects, faces, or scenes.

Deep learning has further expanded this potential, allowing the training of networks with dozens or hundreds of layers to perform tasks such as facial recognition, image classification, anomaly detection, semantic segmentation, and many other applications. These deep architectures learn autonomously from large volumes of data, which makes their performance highly superior to traditional methods in various visual tasks. As stated by Goodfellow, Bengio, and Courville (2016), deep learning has enabled computer vision to reach levels of accuracy close to—and in some cases surpassing—human performance, especially in controlled environments.

Thus, understanding the basic concepts of computer vision, image processing, and convolutional neural networks is fundamental for studying contemporary applications of machine-based visual recognition. These theoretical foundations support current advances and provide a solid basis for the critical analysis of uses, limitations, and ethical implications of technologies based on artificial vision.

FACIAL RECOGNITION: TECHNICAL FUNCTIONING

Facial recognition, within the field of computer vision, is a complex technical process that involves multiple stages intended to identify or verify the identity of individuals from images or videos. Its modern operation is deeply linked to the use of deep neural networks, which enable precise analysis of visual patterns. For this technology to operate, the system must initially detect and locate a face in the image; then analyze its structural characteristics; and, finally, compare them to a previously registered database. According to Zhao et al. (2003), facial recognition combines techniques of detection, feature

extraction, and classification, forming a pipeline that transforms a face into numerical information capable of representing a person's identity.

The first stage, facial detection, consists of finding the exact region in which the face is present. Classic algorithms such as Viola and Jones's Haar Cascade were widely used for their speed and efficiency. However, modern approaches such as MTCNN (Multi-Task Cascaded Convolutional Networks), SSD, and YOLO offer greater accuracy, being capable of identifying faces under variations in lighting, angle, and expression. After detecting the face, the analysis of facial patterns begins, which involves identifying structural elements such as the position of the eyes, the shape of the nose, the contour of the face, and the distance between specific points. This analysis captures facial geometry, which Bojanowski and Joulin (2017) highlight as essential for representing identity consistently, even in the face of small pose variations.

The next stage, and perhaps the most crucial, is the extraction of facial features. In modern models, this extraction occurs through convolutional neural networks, which transform the face into a high-dimensional numerical vector known as a facial embedding. This embedding functions as a kind of "digital signature" of the face, representing a person's unique patterns in a compact and comparable form. The system then uses similarity metrics—such as Euclidean or cosine distance—to compare the vector of the analyzed face with vectors stored in the database. The smaller the distance between two embeddings, the greater the probability that they refer to the same person. According to Schroff, Kalenichenko, and Philbin (2015), this approach has allowed facial recognition to reach levels of accuracy previously considered impossible. Several algorithms and datasets have contributed significantly to the development of these systems. Labeled Faces in the Wild (LFW), for example, became one of the first highly impactful benchmarks, enabling evaluation of model accuracy in real, uncontrolled conditions. VGGFace, developed by the Visual Geometry Group, further expanded the field by providing a robust dataset and a high-performance pre-trained model. FaceNet, proposed by Schroff et al. (2015), revolutionized facial recognition by introducing the concept of triplet loss, which directly optimizes distances between embeddings, increasing model accuracy in verification and identification tasks. These advances enabled the technology to be incorporated into smartphones, security systems, digital platforms, and authentication tools with increasing precision and efficiency.

As a result, facial recognition has evolved into a technology capable of operating at scale, offering speed and high performance. However, its complex technical functioning requires careful analyses of its social impacts, especially regarding privacy, bias, and ethical use—fundamental aspects for understanding its implications in the contemporary scenario of artificial intelligence.

RECENT ADVANCES

Recent advances in facial recognition reflect the rapid evolution of computer vision driven by deep learning, resulting in systems that are increasingly precise, efficient, and widely disseminated in everyday life. One of the most significant progress points concerns the continuous increase in model accuracy. Thanks to deep neural networks and large datasets, current systems can operate with extremely low error rates, approaching—and in some contexts surpassing—the human ability to identify faces. According to Taigman et al. (2014), the development of more robust architectures, combined with techniques such as data augmentation and contrastive learning, has contributed to building models capable of recognizing individuals even under adverse conditions, such as variations in lighting, different angles, and changes in facial expression.

Another important advance is related to the implementation of these technologies in mobile devices. The popularization of systems such as Face ID, present in Apple smartphones, demonstrates the maturity achieved by the technology by allowing facial authentication to be used safely and quickly on millions of devices. These systems use infrared sensors, depth cameras, and deep learning models integrated with hardware, ensuring high performance even with energy and processing constraints. As Schroff et al. (2015) and Deng et al. (2019) emphasize, advances in facial recognition algorithms, alongside the development of optimized computational architectures, have made real-time processing directly on devices possible, reducing the need to send biometric data to external servers and contributing to greater privacy preservation. This perspective aligns with the critical analyses of Zuboff (2019) and Lyon (2018), which point out how digital surveillance and the use of personal data have become central in contemporary society, reinforcing the importance of technological solutions that reconcile innovation and protection of privacy.

Moreover, the use of facial recognition has expanded significantly across digital platforms. Applications from social networks and video services, such as Instagram, TikTok, and Snapchat, employ computer vision models to apply facial filters, perform expression mapping, and create complex interactive effects. In these contexts, the technology is not merely functional but also part of the aesthetic and entertainment experience, showing how AI has become accessible to the average user. In parallel, access control systems in corporate environments, airports, and public spaces have adopted advanced identification algorithms to replace cards, passwords, and physical documents, improving operational efficiency and security.

Another fundamental point in the area's progress is the emergence and popularization of pre-trained deep learning models. Networks such as VGGFace2, FaceNet, and ArcFace have been trained on millions of images and made available to researchers and developers, democratizing access to cutting-edge technologies. These pre-trained models significantly reduce the time and resources needed to build

facial recognition systems, allowing companies and researchers to adapt architectures to their specific needs without having to train a network from scratch. As Deng et al. (2019) observe, this approach fosters the development of more robust and efficient solutions, contributing to the rapid evolution and dissemination of the technology.

Thus, recent advances in facial recognition demonstrate not only the area's technical maturation but also its growing insertion into everyday life, reinforcing the need for ethical and regulatory debates in the face of its increasingly sophisticated and comprehensive use.

RISKS AND CHALLENGES

The risks and challenges associated with facial recognition accompany the rapid expansion of this technology and reveal ethical, technical, and social issues that cannot be ignored. One of the main problems concerns privacy and the protection of biometric data. Unlike a password or card, the face is a unique and permanent identifier that cannot be "changed" if compromised. According to Zuboff (2019), technologies that capture and analyze sensitive human data significantly expand forms of surveillance and exploitation, making the discussion about consent, security, and limits in the use of biometric information urgent. Brazil's General Data Protection Law (LGPD) classifies biometric data as sensitive, reinforcing that its use requires justification, necessity, and enhanced protection.

Another important risk is mass surveillance and the loss of anonymity in public spaces. Camera systems integrated with facial recognition algorithms make it possible to identify people in crowds, track movements, and reconstruct behavior patterns. Lyon (2018) highlights that such systems, when used without transparency and regulation, expand the surveillance power of state and corporate agents, creating an environment of constant monitoring. This situation can generate harmful effects on democracy, freedom of expression, and the right to come and go, especially when technology is used for social control or political repression. Algorithmic biases represent another serious challenge. Several studies demonstrate that facial recognition systems exhibit significantly higher error rates for women, Black people, and other minorities. The study by Buolamwini and Gebru (2018), conducted at MIT, showed that commercial systems had accuracy above 99% for white men but alarming failure rates when identifying Black women. These results show that the technology can reinforce historical inequalities, generate institutional discrimination, and compromise equity in applications such as policing, border control, or recruitment.

The misuse of technology by governments or companies is also a growing concern. In authoritarian contexts, facial recognition can be used to monitor political opponents, journalists, or vulnerable groups, increasing risks of persecution and repression. In the private sector, its use without consent can fuel abusive practices, such as tracking consumers, covert data collection, or inappropriate

applications in workplace environments. As O'Neil (2016) points out, poorly regulated algorithmic systems tend to operate as "weapons of math destruction," affecting individuals invisibly and without mechanisms for contestation.

Finally, there are technical vulnerabilities that challenge the reliability of these systems. Deepfakes—AI-generated videos capable of faithfully reproducing a person's face—represent a threat to digital security and can be used for fraud, blackmail, manipulation of public opinion, or identity theft. Likewise, spoofing attacks, such as the use of 3D masks, printed photos, or projections, can deceive facial recognition systems, demonstrating that these mechanisms are not always infallible. As reported by Tolosana et al. (2020), facial forgery techniques evolve rapidly, requiring the creation of robust and up-to-date defenses.

Given these risks, it is essential that the development and use of facial recognition technologies be accompanied by clear policies, effective oversight, and ethical reflection. The pursuit of innovation must go hand in hand with the protection of fundamental rights, ensuring that technological advances do not become instruments for violating individual and collective freedoms.

CONCLUSION

The study made it possible to understand that computer vision applied to facial recognition represents one of the most significant advances in contemporary artificial intelligence, bringing together sophisticated deep learning techniques, large datasets, and increasing computational capacity to perform tasks once exclusive to human perception. The analysis showed that, from a technical standpoint, the technology has evolved significantly in recent decades, achieving high accuracy rates and becoming widely used in mobile devices, digital platforms, authentication systems, and surveillance mechanisms. This expansion has been driven by convolutional neural networks capable of extracting facial features with high efficiency, producing robust embeddings that are quickly and reliably comparable across different usage contexts.

Nevertheless, despite its advances, facial recognition has also proven to be a technology marked by significant risks that must be considered critically. Issues related to privacy and the processing of biometric data proved central, since the face is a permanent, sensitive identifier that cannot be replaced in the event of a leak or misuse. The research also evidenced that such systems expand the possibilities for large-scale surveillance and monitoring, threatening fundamental rights such as anonymity and freedom of movement, especially in public environments and in societies with little transparency in the actions of governmental and corporate institutions.

Furthermore, the algorithmic biases identified in the literature underscore the need for caution, as they show that women, Black people, and other minorities continue to face higher error rates in facial

recognition—something that can result in institutional discrimination, injustices in security systems, and inequalities reinforced through automated decisions. It was also found that the technology is subject to technical vulnerabilities, such as deepfakes and spoofing attacks, which can circumvent authentication mechanisms and undermine the reliability of systems that rely exclusively on facial identification.

Accordingly, the work concludes that although facial recognition represents a milestone in the evolution of artificial intelligence and offers numerous benefits in terms of practicality, security, and automation, its use must be accompanied by clear regulations, constant oversight, and policies that ensure transparency, equity, and protection of sensitive data. The analysis showed that the adoption of this technology can only be considered socially responsible when a balance is established between innovation and fundamental rights, preventing technical advances from turning into instruments of abusive surveillance or discrimination. Thus, we highlight the importance of governments, companies, and civil society acting jointly to build ethical guidelines, control mechanisms, and safe development practices, ensuring that facial recognition is applied in a fair, reliable manner aligned with democratic values.

REFERENCES

1. Bojanowski, Piotr; Joulin, Armand. Unsupervised learning by predicting noise. In: International Conference on Machine Learning, 2017. Available at: https://arxiv.org/abs/1704.05310. Accessed on: 15 Nov. 2025.

2. Buolamwini, Joy; Gebru, Timnit. Gender Shades: Intersectional accuracy disparities in commercial gender classification. In: Proceedings of the 1st Conference on Fairness, Accountability and Transparency. PMLR, v. 81, p. 77–91, 2018. Available at: https://proceedings.mlr.press/v81/buolamwini18a.html. Accessed on: 15 Nov. 2025.

3. Deng, Jiankang et al. ArcFace: Additive angular margin loss for deep face recognition. In: IEEE/CVF Conference on Computer Vision and Pattern Recognition, 2019. Available at: https://openaccess.thecvf.com/content_CVPR_2019/html/Deng_ArcFace_Additive_Angular_Margin_Loss_for_Deep_Face_Recognition_CVPR_2019_paper.html. Accessed on: 15 Nov. 2025.

4. Gonzalez, Rafael C.; Woods, Richard E. Digital Image Processing. 4. ed. Pearson, 2019.

5. Goodfellow, Ian; Bengio, Yoshua; Courville, Aaron. Deep Learning. Cambridge: MIT Press, 2016.

6. LeCun, Yann; Bengio, Yoshua; Hinton, Geoffrey. Deep learning. Nature, v. 521, p. 436–444, 2015. Available at: https://www.nature.com/articles/nature14539. Accessed on: 15 Nov. 2025.

7. Lyon, David. The Culture of Surveillance: Watching as a Way of Life. Cambridge: Polity Press, 2018.

8. O'Neil, Cathy. Weapons of Math Destruction: How Big Data Increases Inequality and Threatens Democracy. New York: Crown, 2016.

9. Schroff, Florian; Kalenichenko, Dmitry; Philbin, James. FaceNet: A unified embedding for face recognition and clustering. In: Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, 2015. Available at: https://arxiv.org/abs/1503.03832. Accessed on: 15 Nov. 2025.

10. Szeliski, Richard. Computer Vision: Algorithms and Applications. 2. ed. Cham: Springer, 2022.

11. Taigman, Yaniv et al. DeepFace: Closing the gap to human-level performance in face verification. In: Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2014, p. 1701-1708. Available at: https://www.cv-foundation.org/openaccess/content_cvpr_2014/html/Taigman_DeepFace_Closing_the_2014_CVPR_paper.html. Accessed on: 15 Nov. 2025.

12. Tolosana, Ruben et al. DeepFakes and beyond: A survey of face manipulation and fake detection. Information Fusion, 2020. Available at: https://arxiv.org/abs/2001.00179. Accessed on: 15 Nov. 2025.

13. Viola, Paul; Jones, Michael. Rapid object detection using a boosted cascade of simple features. In: IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 2001, v. 1, p. I-511–I-518.
Available at: https://www.researchgate.net/publication/3940582_Rapid_Object_Detection_using_a_Boosted_Cascade_of_Simple_Features. Accessed on: 15 Nov. 2025.

14. Zhao, Wenyi et al. Face recognition: A literature survey. ACM Computing Surveys, v. 35, n. 4, p. 399–458, 2003. Available at: https://dl.acm.org/doi/10.1145/954339.954342. Accessed on: 15 Nov. 2025.

15. Zuboff, Shoshana. The Age of Surveillance Capitalism: The Fight for a Human Future at the New Frontier of Power. New York: PublicAffairs, 2019.

ISBN: 978-65-83849-24-3

Aurum EDITORA

CHAPTER 12

NATIONAL POLICY ON SPECIALISED HEALTH CARE (PNAES): PROGRESS, CHALLENGES AND STRATEGIES FOR INTEGRATION

https://doi.org/10.63330/aurumpub.021-012

Alessandro Martins Ribeiro[1], Drieli Oliveira Silva[2], Marcia Viviane de Araújo Sampaio[3] and Poliana Cardoso Martins[4]

ABSTRACT

The objective of this theoretical essay is to analyse the development of the National Policy for Specialised Health Care (PNAES), established by Ordinance GM/MS No. 1,604/2023, which aims to reorganise specialised care in the SUS, overcoming historical challenges of fragmentation, disarticulation, and unequal access. The results highlight advances in the integration between Primary Health Care (PHC) and specialised services through mechanisms such as bottom-up territorial planning, shared regulation, matrix support, teleconsultations and joint clinical protocols, in addition to the mandatory linking of specialised services to vulnerable territories. Experiences in states such as Ceará and municipalities in Bahia illustrate the effectiveness of regionalisation, consortium management, and regulation in increasing access and improving the quality of care. There has also been a strengthening of the More Access to Specialists Programme, with widespread adherence and a historic increase in the number of consultations and examinations. The discussion points out that, despite advances, structural challenges remain related to financial sustainability, technological modernisation, retention of professionals, and strengthening of municipal governance, which are essential for effective integration and continuity of care. The conclusion emphasises that the PNAES inaugurates an innovative phase of specialised care, focused on integration, co-responsibility and social justice, whose effectiveness depends on political commitment, social participation and strengthening.

Keywords: Specialised Care; Healthcare Network; Inclusion of doctors; Territorialisation.

[1] M.A. in Health Sciences (UFVJM)
Graduate Program in Collective Health
Federal University of Bahia
Multidisciplinary Institute of Health (UFBA/IMS). Vitória da Conquista, BA
E-mail: alessandroribeiro@ufba.br
ORCID: https://orcid.org/0000-0002-9065-4678
[2] M.A. in Collective Health (UFBA/IMS)
Graduate Program in Collective Health
Federal University of Bahia
Multidisciplinary Institute of Health (UFBA/IMS). Vitória da Conquista, BA
ORCID: https://orcid.org/0000-0002-7735-6895
[3] M.A. in Public Health from the Oswaldo Cruz Foundation (Fiocruz/BA)
Graduate Program in Collective Health
Federal University of Bahia
Multidisciplinary Institute of Health (UFBA/IMS). Vitória da Conquista, BA
LATTES: http://lattes.cnpq.br/7362147284492964
[4] Ph.D. in Public Health from the Federal University of Minas Gerais (UFMG)
Graduate Program in Collective Health
Federal University of Bahia
Multidisciplinary Institute of Health (UFBA/IMS). Vitória da Conquista, BA
ORCID: https://orcid.org/0000-0002-6698-0289

INTRODUCTION

THEORETICAL ESSAY

The development of the National Policy for Specialized Health Care (PNAES) was marked by an important "International Seminar on Specialized Care" which, by bringing together SUS managers, researchers, and professionals, outlined a historical panorama of the main challenges faced by specialized care in Brazil. The event made evident the effects of the dismantling of public policies beginning in 2016, such as the interruption of structuring programs and the weakening of integration between levels of care, especially between Primary Care and medium- and high-complexity services. Based on this diagnosis, proposals were discussed to overcome a model still centered on a hospital-centric and biomedical logic, of limited resoluteness and poorly linked to the population's needs. Among the main challenges debated were the reorganization of services according to the logic of Health Care Networks (RAS), the qualification of care regulation, the strengthening of Primary Care, digital transformation, modernization of the technological apparatus, and the retention of professionals in areas of greater vulnerability. From these reflections, the PNAES guidelines were outlined, aimed at building a model of comprehensive, regionalized, efficient care committed to equitable access to health (Brazil, 2023).

The National Policy for Specialized Health Care (PNAES), instituted by Ordinance GM/MS No. 1,604/2023, represents a milestone in reorganizing specialized care within the Unified Health System (SUS). It emerges as a response to historical challenges, such as fragmentation of services and lack of integration with Primary Health Care (PHC) (Tesser and Poli, 2017; Brazil, 2023). The policy establishes nine structuring axes, among which stand out bottom-up territorial planning, integration with PHC, and equitable regulation of access—elements that directly engage with criticisms raised by Tesser and Poli (2017) regarding the historical disarticulation among care levels.

PNAES proposes a care model centered on user needs, with an emphasis on co-responsibility between PHC teams and specialized services. This alignment corroborates the recommendations of Elo et al. (Brazil, 2023), who highlight access regulation as an essential mechanism to ensure equity. The policy provides for the implementation of shared protocols and interprofessional communication systems, strategies that can reduce the historical waiting lists identified by Tesser and Poli (2017) in studies on access to specialties.

One significant advance is the provision for mandatory linkage between specialized services and rural and remote PHC territories (Fausto et al., 2023; Brazil, 2023). This guideline harkens back to care gaps that exist across the 5,570 municipalities, 26 states, and the Federal District, with respect to the low resoluteness of primary care for complex cases; thus, the same policy institutes mechanisms such as systematic teleconsultations and matrix support, devices that enhance PHC's clinical capacity—an aspect crucial as pointed out by Fausto et al. (2023) in analyses of care regulation.

Despite the innovative framework, structural challenges persist. The policy does not change existing financing models, maintaining dependence on temporary federal incentives—a fragility already noted in studies of prior SUS policies (Massuda, 2020). The sustainability of new care models will depend on tripartite agreements and the strengthening of integrated information systems, critical factors for the success of health policies as demonstrated in analyses of thematic network implementation (Lotta, 2019).

Specialized services must be linked to specific territories and to a defined number of PHC teams, ensuring population assignment (Fausto et al., 2023). This guideline responds to the historical critique of disarticulation among care levels, as noted by Tesser and Poli (2017). Bottom-up, regionalized planning (Axis I of PNAES) ensures that the organization of flows considers local needs and inter-federative agreements (Brazil, 2023).

The ordinance requires the joint development of clinical and referral protocols between PHC and specialized services (Art. 16, III), with records in a shared electronic health record (Brazil, 2024). Although PNAES does not alter funding structures, Axis IX provides incentives for payment models based on performance and care integration; thus, Ordinance 3,492/2024 advances in this direction by linking federal transfers to the implementation of joint actions between PHC and specialized care (Brazil, 2023; Brazil, 2024).

The instruments of interprofessional support provided for in PNAES constitute important strategies to strengthen integration between Primary Health Care (PHC) and specialized services. Among these, systematic matrix support of PHC teams by specialists stands out, as per Art. 17, I, and teleconsultations and formative second opinions, described in Art. 17, II, which broaden the response capacity of local teams through continuous technical support. Additionally, care navigation seeks to ensure a safe, coordinated transition among different points of the care network. Together, these actions materialize the concept of specialized backup to PHC, as defined in the regulation manual, promoting greater resoluteness, continuity of care, and network articulation (Brazil, 2023; Brazil, 2024).

The evaluation models of the National Policy for Specialized Health Care (PNAES) are structured multidimensionally, articulating three central axes designed to ensure the effectiveness and quality of services offered. The first axis encompasses performance evaluation, based on indicators such as resoluteness, average waiting time, and the rate of inappropriate referrals, allowing measurement of system efficiency. The second axis addresses service certification, using criteria of care quality and integration with thematic networks, in a strategy inspired by successful experiences in hospital evaluation. Finally, the third axis refers to continuous monitoring, made possible by an enhanced Ambulatory Information System (SIA), which includes modules aimed at shared regulation, strengthening the management and transparency of care processes (Brazil, 2023; Brazil, 2024; Tesser; Poli, 2017).

These models incorporate lessons from previous programs, such as the SUS Evaluation Program for Qualification (2011), which had already pointed to the need for indicators sensitive to integration among care levels (Elo et al., 2021; Brazil, 2023). PNAES advances by establishing quantitative targets for reducing waiting lists and criteria for computerized referral/counter-referral (Brazil, 2024).

As Ribeiro (2025) discusses, regulation must be understood in its ethical, political, and technical dimensions, articulating criteria of equity, efficiency, and transparency. In the context of PNAES, this translates into the construction of agreed regulatory flows, the use of computerized systems, and co-responsibility among managers and professionals at different care levels. When well-structured, regulation enhances the role of regionalized networks, expands the resoluteness of Primary Health Care, and ensures timely, high-quality access to specialized services.

The decentralization of management, while expanding municipal autonomy, also reveals weaknesses related to technical capacity, local political instability, and difficulties in intergovernmental articulation, which compromise integration among care levels and the effectiveness of regulatory and evaluative processes. These challenges directly impact the implementation of policies such as the National Policy for Specialized Health Care (PNAES), as they hinder the construction of integrated flows, efficient access regulation, and the consolidation of regionalized care networks. According to Ribeiro, Braga, and Souza (2025), overcoming these limitations requires strengthening municipal governance, investing in continuing education, valuing spaces for social participation, and adopting innovative management and financing strategies. Thus, the success of PNAES depends not only on normative guidelines but on an integrated approach sensitive to the specificities and challenges of the Brazilian municipal context—an indispensable condition for realizing a model of specialized care tailored to the health singularities of the territory (Mendes, 2013).

The study by Castro and Campos (2016) presents results that contribute significantly to the discussion on PNAES, especially regarding integration between specialized care and Primary Health Care (PHC). The authors demonstrate that matrix support acts as an important articulator of interprofessional relations, promoting continuous exchange of knowledge and co-responsibility between PHC teams and specialized services. This articulation favors the qualification of care, increases case resoluteness, and avoids unnecessary referrals to specialized care.

For Rossi and Chaves (2015), the implementation of Specialized Oral Health Care is a formative example of this integration among points in the health care network, analyzed in two municipalities in Bahia: Vitória da Conquista and Feira de Santana. Both municipalities present comprehensive Primary Care coverage, which enabled an in-depth assessment of the processes of implementing Dental Specialty Centers (CEOs) in contexts with consolidated basic structures. The choice of these municipalities made it possible to identify how integration strategies between primary and specialized care manifest in distinct

realities, evidencing specific advances and challenges. While Vitória da Conquista had formal spaces for dialogue among teams—favoring articulation and the construction of flows and protocols—Feira de Santana faced difficulties consolidating these practices, which impacted the effectiveness of access regulation and the quality of specialized care. These findings underscore the importance of territorial planning, efficient regulation, and institutional support for service qualification—central elements for the realization of PNAES.

The lessons from Rossi and Chaves (2015) speak directly to the principles and challenges of PNAES. The experience of the municipalities analyzed reinforces the importance of mechanisms of integration between primary and specialized care, the need for well-defined regulatory protocols, and the central role of participatory management and continuing education. Such aspects are fundamental to realizing the structuring axes of PNAES, especially in terms of network articulation, access regulation, and qualification of specialized services.

The experience of Ceará was the most successful, given the expansion of access to specialized care—especially in regions historically underserved. The implementation of Regional Polyclinics, with consortium management among municipalities, enabled the provision of specialized consultations, exams, and procedures in territories previously lacking these services. The strengthening of access regulation, with computerized systems and agreed protocols, contributed to greater equity and efficiency in the use of resources (Almeida et al., 2019).

The Ceará model shows that regionalization, consortium management, and inter-federative agreements are effective strategies to ensure equitable access to specialized care and promote integration in care networks. It also highlights the need to strengthen access regulation, invest in continuing education, and institutionalize evaluation processes—central aspects for the effectiveness of PNAES's structuring axes (Almeida et al., 2019).

According to official data from the Ministry of Health, the More Access to Specialists Program (PMAE), the operational arm of PNAES, already has the adherence of 99.2% of Brazilian municipalities and 100% of states, covering 97.5% of the country's health regions. Between 2024 and 2026, the goal is to perform more than one million surgeries per year, in addition to significantly expanding specialized consultations and exams. In 2023, the SUS recorded an increase of 13% in the total number of consultations with specialists, rising from 843.7 million in 2022 to 953.1 million, and a growth of 13.3% in the total number of diagnostic exams, which went from 1 billion to 1.1 billion. These numbers reflect the highest production volume in SUS history since 2010, resulting from a record investment of R$4.8 billion in oral health and R$31.5 billion planned for the next four years in the More Access to Specialists Program and the New PAC. The report "Agora tem especialistas" by Rafael Machado and Rebeca Kroll

on the Futuro da Saúde portal highlights concrete advances in expanding access to specialized care within the SUS, especially in regions historically lacking this service (Machado; Kroll, 2024).

PNAES represents a strategic advance in reorganizing specialized care within the Unified Health System, responding to historical challenges of fragmentation, disarticulation, and inequality in access to medium- and high-complexity services (Brazil, 2023). The analysis of national and international experiences, as well as field studies in different regions of Brazil, shows that effective integration between primary and specialized care is fundamental for care qualification, reduction of waiting lists, and expansion of system resoluteness.

The instruments provided in PNAES—such as bottom-up territorial planning, shared regulation, matrix support, use of digital technologies, and multidimensional evaluation—demonstrate potential to overcome the hospital-centric model and promote regionalized care networks that are more equitable and centered on user needs. Successful experiences, such as regionalization in Ceará, implementation of CEOs in Bahia, and strengthening of matrix support, reinforce that regional governance, inter-federative agreements, and continuing education are essential pillars for the policy's success (Castro; Gastão, 2016; Rossi & Chaves, 2015; Almeida et al., 2019).

Despite advances, structural challenges persist—such as financial sustainability, the need for technological modernization, retention of professionals in vulnerable areas, and institutionalization of evaluation processes. The recent substantial increase in the volume of specialized consultations, exams, and surgeries, together with the near-universal adherence of municipalities to the More Access to Specialists Program, reveals that SUS has reached a new production level, but also demands constant vigilance to guarantee quality, equity, and continuity of care.

Therefore, PNAES inaugurates a new phase for specialized care in Brazil, based on integration, co-responsibility, and the ongoing pursuit of efficiency and social justice. Its success will depend on political commitment, active participation of managers, professionals, and users, and the strengthening of regional networks as spaces for innovation, evaluation, and collective construction of the right to health.

REFERENCES

1. Brasil. Conselho Nacional de Saúde. Política Nacional de Atenção Especializada é aprovada pelo Conselho Nacional de Saúde [National Specialized Care Policy is approved by the National Health Council]. 19 Oct. 2023. Accessed on: 4 Sept. 2024.

2. Brasil. Portaria GM/MS nº 1.604, de 18 de outubro de 2023 [Ordinance GM/MS No. 1,604, of October 18, 2023]. Institui a Política Nacional de Atenção Especializada em Saúde (PNAES) [Establishes the National Specialized Care Policy in Health (PNAES)]. Diário Oficial da União, 19 Oct. 2023.

3. Brasil. Portaria GM/MS nº 3.492, de 11 de abril de 2024 [Ordinance GM/MS No. 3,492, of April 11, 2024]. Estabelece incentivos financeiros para integração entre atenção primária e especializada no SUS [Establishes financial incentives for integration between primary and specialized care in the SUS]. Diário Oficial da União, 2024.

4. Brasil. Seminário Internacional de Atenção Especializada. Ministério da Saúde. Política Nacional de Atenção Especializada em Saúde [National Specialized Care Policy]. Brasília: Ministério da Saúde, 2023. Available at: https://redeaps.org.br/wp-content/uploads/2023/06/Politica-Nacional-de-Atencao-Especializada-em-Saude.pdf. Accessed on: 30 May 2025.

5. Almeida, P. F. de; Giovanella, L.; Martins, M. T.; Lima, L. D. de. Redes regionalizadas e garantia de atenção especializada em saúde: a experiência do Ceará, Brasil [Regionalized networks and guarantee of specialized health care: the experience of Ceará, Brazil]. Ciência & Saúde Coletiva, v. 24, n. 12, p. 4527–4540, 2019. Available at: https://doi.org/10.1590/1413-812320182412.25562019. Accessed on: 26 May 2025.

6. Castro, Cristiane Pereira de; Campos, Gastão Wagner de Sousa. Apoio matricial como articulador das relações interprofissionais entre serviços especializados e atenção primária à saúde [Matrix support as an articulator of interprofessional relations between specialized services and primary health care]. Physis: Revista de Saúde Coletiva, v. 26, n. 2, p. 455–481, 2016. Available at: https://doi.org/10.1590/S0103-73312016000200007. Accessed on: 22 May 2025.

7. Elo, E. A.; Gomes, G. G.; Carvalho, J. O.; Pereira, P. H. B.; Guabiraba, K. P. L. A regulação do acesso à atenção especializada e a Atenção Primária à Saúde nas políticas nacionais do SUS [Regulation of access to specialized care and Primary Health Care in the national SUS policies]. Physis, v. 31, n. 1, e310109, 2021.

8. Fausto, M. C. R.; Almeida, P. F. de; Bousquat, A.; Lima, J. G.; Santos, A. M. dos; Seidl, H.; Mendonça, M. H. M. de; Cabral, L. M. da S.; Giovanella, L. Atenção Primária à Saúde em municípios rurais remotos brasileiros: contexto, organização e acesso à atenção integral no Sistema Único de Saúde [Primary Health Care in remote rural Brazilian municipalities: context, organization, and access to comprehensive care in the Unified Health System]. Saúde e Sociedade, v. 32, n. 1, e220382pt, 2023. Available at: https://doi.org/10.1590/S0104-12902023220382pt. Accessed on: 26 May 2025.

9. Lotta, Gabriela. A política pública como ela é: contribuições dos estudos sobre implementação para a análise de políticas públicas [Public policy as it is: contributions from implementation studies to public policy analysis]. In: Lotta, Gabriela (org.). Teorias e análises sobre implementação de políticas públicas no Brasil. Brasília: Enap, 2019. p. 11–38.

10. Machado, R.; Kroll, R. Agora tem especialistas [Now there are specialists]. Futuro da Saúde, 2024. Available at: https://futurodasaude.com.br/agora-tem-especialistas/. Accessed on: 19 May 2025.

11. Massuda, A. Mudanças no financiamento da Atenção Primária à Saúde no Sistema de Saúde Brasileiro: avanço ou retrocesso? [Changes in the financing of Primary Health Care in the Brazilian Health System: progress or setback?]. Ciência & Saúde Coletiva, v. 25, n. 4, p. 1181–1188, 2020. Available at: https://doi.org/10.1590/1413-81232020254.01022020. Accessed on: 28 May 2025.

12. Mendes, E. V. 25 anos do Sistema Único de Saúde: resultados e desafios [25 years of the Unified Health System: results and challenges]. Estudos Avançados, v. 27, n. 78, p. 27–34, 2013. Available at: https://doi.org/10.1590/S0103-40142013000200003. Accessed on: 30 May 2025.

13. Ribeiro, A. M. Ensaio teórico sobre a regulação de acesso na saúde [Theoretical essay on access regulation in health]. Aurum Editora, 2025. p. 1–12.

14. Ribeiro, A. M.; Braga, W. dos S.; Souza, R. B. de. Desafios sociais e políticos do modelo sanitarista no Brasil: impactos e limitações na gestão municipal [Social and political challenges of the sanitist model in Brazil: impacts and limitations in municipal management]. Revista de Saúde Pública de Mato Grosso do Sul, Campo Grande, Mato Grosso do Sul, Brasil, v. 7, n. 2, p. 07–22, 2025. DOI: 10.70630/rspms.v7n2.319. Available at: https://revista.saude.ms.gov.br/index.php/rspms/article/view/319. Accessed on: 1 Jun. 2025.

15. Rossi, T. R. A.; Chaves, S. C. L. Implementação da Atenção Especializada em Saúde Bucal em dois municípios na Bahia/Brasil [Implementation of Specialized Oral Health Care in two municipalities in Bahia/Brazil]. Saúde em Debate, v. 39, n. spe, p. 196–206, 2015. Available at: https://doi.org/10.5935/0103-1104.2015S005186.

16. Tesser, Charles Dalcanale; Poli, Paulo. Atenção especializada ambulatorial no Sistema Único de Saúde: para superar um vazio [Ambulatory specialized care in the Unified Health System: to overcome a gap]. Ciência & Saúde Coletiva, v. 22, n. 3, p. 941–951, 2017. Available at: https://doi.org/10.1590/1413-81232017223.18842016. Accessed on: 1 Jun. 2025.

ISBN: 978-65-83849-24-3

HEMATOLOGICAL SEQUELAE AND ALTERATIONS IN THE POST–SARS-COV-2 INFECTION SYNDROME: A LITERATURE REVIEW

https://doi.org/10.63330/aurumpub.021-013

Amauri Pereira de Souza[1]

ABSTRACT

This article aimed to identify and discuss the main hematological sequelae associated with Covid-19 infection, caused by the SARS-CoV-2 virus. This study is a literature review addressing general aspects of the pandemic, characteristics of the etiological agent, and clinical manifestations of the disease, with emphasis on symptoms and post-infection sequelae. Particular attention is given to the impact of Covid-19 on the human hematological system. The analyzed studies indicate that, although significant progress has been made in understanding post-Covid-19 complications, there is still no definitive consensus regarding the extent and pathophysiological mechanisms of these sequelae. However, available evidence suggests that SARS-CoV-2 infection may trigger an exacerbated inflammatory response, characterized by excessive cytokine release, known as a "cytokine storm." Although this process plays a central role in immune defense, it may also lead to damage to healthy cells and tissues. In the hematological context, this inflammatory response has been associated with clinically relevant alterations, including immune-mediated disorders and hematological diseases, such as autoimmune hemolytic anemia.

Keywords: SARS-CoV-2; Symptoms; Hematological Sequelae.

[1] Master's in Biochemistry and Molecular Biology
Federal University of Western Bahia (UFOB)
E-mail: amauri.souza@ufob.edu.br
LATTES: https://lattes.cnpq.br/3018271127690836

INTRODUCTION

The first country to identify cases of infection caused by the SARS-CoV-2 virus was China, at the end of 2019; however, due to the virus's high transmissibility, the disease spread rapidly, reaching several countries around the world, including Brazil. Covid-19 presents a broad spectrum of clinical manifestations, ranging from asymptomatic cases to severe forms, with the most frequently reported symptoms being fever, dry cough, and dyspnea. In addition to respiratory involvement, clinical evidence shows that infection by SARS-CoV-2 is associated with important hematological alterations, such as lymphopenia, coagulation dysfunctions, and exacerbated inflammatory responses, which correlate with greater severity and worse prognosis. In more severe cases, the disease may progress to bilateral pulmonary infiltration, acute respiratory distress syndrome (ARDS), respiratory failure, and multiple organ failure, including hepatic, cardiac, renal, and hematological involvement (Guan et al., 2020). These systemic alterations may persist after the acute phase of infection, contributing to the development of post–Covid-19 syndrome, characterized by prolonged clinical manifestations and a significant impact on hematological homeostasis.

Since the beginning of the pandemic, countless studies have been conducted to measure the sequelae resulting from Covid-19. Nevertheless, to date, it is not yet possible to precisely determine all the physical and functional damage that SARS-CoV-2 infection may cause in the long term. Evidence indicates that the most severe adverse effects are often associated with the need for invasive mechanical ventilation, which may result in physical, cognitive, and psychiatric impairments, negatively affecting the quality of life of individuals and their families. Additionally, it is observed that patients previously diagnosed with Covid-19 may, in the post-infection period, present complications involving the respiratory, neurological, cardiovascular, gastrointestinal, hematological, and urinary systems (Lira *et al*., 2021).

Given this context, the present study proposes a discussion on Covid-19, highlighting its main symptoms and sequelae, with emphasis on the dysfunctions triggered in the hematological system. Accordingly, the general objective of this work is to identify and describe the main hematological consequences associated with infection by SARS-CoV-2.

The study was developed through a literature review organized from bibliographic research. According to Cruz (2010), this type of research constitutes the initial stage of any scientific investigation, regardless of the problem under study, aiming to provide the researcher with prior knowledge of the existing scientific production on the topic.

Complementarily, Lakatos and Marconi (2010) define bibliographic research as one that encompasses all publicly available bibliography concerning the investigated subject, including standalone publications, bulletins, newspapers, magazines, books, studies, monographs, and theses, as well as other

means of communication. The development of this work was based predominantly on the analysis of scientific articles and recent publications in specialized journals that address the Covid-19 pandemic and its systemic repercussions, with special attention to hematological alterations.

OBJECTIVE

To investigate, through a literature review, the sequelae in the hematological system resulting from SARS-CoV-2 infection in patients recovered from the acute phase of Covid-19, considering its interface with different physiological systems in the context of post–Covid-19 syndrome, as well as to describe the main hematological alterations associated with this infection.

JUSTIFICATION

This research is justified by the need to systematize and deepen scientific knowledge regarding the hematological sequelae observed after Covid-19 infection. Although significant advances have been made in understanding the disease's pathophysiological mechanisms, the hematological repercussions associated with post–Covid-19 syndrome still demand more consistent and integrated investigation.

SARS-CoV-2 infection may trigger an exacerbated inflammatory response, characterized by the release of a cascade of immune system signaling proteins—especially cytokines and chemokines—responsible for intercellular communication among immune cells. Although this response is essential for controlling infection, its dysregulated activation may result in damage to healthy cells and tissues, favoring the development of clinically relevant complications, such as autoimmune diseases—exemplified by autoimmune hemolytic anemia.

Additionally, evidence indicates that the most severe adverse effects of Covid-19 are often associated with the need for invasive mechanical ventilation, which may lead to persistent alterations in multiple physiological systems, including the respiratory, neurological, cardiovascular, gastrointestinal, urinary, and hematological systems. In this context, the analysis of hematological sequelae becomes fundamental for understanding the magnitude of the disease's systemic impact, supporting clinical follow-up strategies, and contributing to the appropriate management of patients in the post-recovery period.

DEVELOPMENT

COVID 19

The pandemic caused by the novel coronavirus began on December 31, 2019, in the city of Wuhan, located in the People's Republic of China, following the identification of several cases of pneumonia of unknown etiology. In January 2020, the outbreak was officially confirmed, displaying rapid

global dissemination. The etiological agent responsible for the disease was named in February 2020 as Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) (PAHO, 2023).

With the accelerated expansion of Covid-19 worldwide, the World Health Organization (WHO) declared, in January 2020, a Public Health Emergency of International Concern (PHEIC), considered the highest level of alert according to the International Health Regulations. Subsequently, in March 2020, the disease was officially classified as a pandemic by the WHO (PAHO, 2023).

Covid-19 is defined as an infectious disease caused by the SARS-CoV-2 coronavirus. According to the Pan American Health Organization (PAHO, 2023), the main symptoms include fever, fatigue, and dry cough. However, additional clinical manifestations may also occur, such as loss of taste and/or smell, nasal congestion, conjunctivitis, sore throat and headache, myalgia, arthralgia, skin rashes, nausea, vomiting, diarrhea, chills, and dizziness.

Moreover, viruses of the *Coronaviridae* family may cause damage across multiple organ systems, including the respiratory, cardiovascular, gastrointestinal, central nervous, and genitourinary systems. Initial clinical manifestations may resemble influenza-like illnesses, with symptoms such as loss of smell and taste, evolving, in more severe cases, to acute respiratory failure, severe pneumonia, and death (Ribeiro *et al*., 2021). In line with these findings, the Secretariat of Primary Health Care (SAPS, 2020) describes common symptoms such as fever between 37 °C and 38 °C, cough, dyspnea, myalgia, fatigue, upper respiratory symptoms, and gastrointestinal manifestations, such as diarrhea.

Regarding the structural characteristics of SARS-CoV-2, it is a virus composed of a single RNA strand located inside a nucleocapsid. The virus is enveloped by a lipid membrane that contains different structural proteins, including envelope proteins and spike proteins, known as Spike (S) proteins, which are responsible for the characteristic crown-like appearance that gives rise to the denomination "coronavirus" (Araújo, 2020).

Complementarily, SARS-CoV-2 belongs to the family *Coronaviridae*, genus *Betacoronavirus*, and subgenus *Sarbecovirus*, presenting structural similarities with other human-pathogenic coronaviruses, such as SARS-CoV, the agent of Severe Acute Respiratory Syndrome, and MERS-CoV, the agent of Middle East Respiratory Syndrome. It is an enveloped virus, approximately spherical in shape, with non-segmented single-stranded RNA. The spike glycoprotein (S) plays a fundamental role in binding to cellular receptors and in evasion of the host's immune response (Khalil; Khalil, 2020).

Coronaviruses are classified as non-segmented, positive-sense single-stranded RNA viruses enveloped by a protein coat, composed mainly of the E protein. Their virions display rounded or oval morphology, with diameters ranging between 60 and 140 nm. Through electron microscopy, prominent surface projections are observed, corresponding to the spike glycoproteins of the Spike protein, which are responsible for the "corona" denomination (Brito *et al*., 2020).

Transmission of SARS-CoV-2 occurs primarily through the expulsion of viral particles by infected individuals, which are inhaled by others, penetrating the nasal mucosa, rich in cells that express the Angiotensin-Converting Enzyme 2 (ACE2) receptor. The virus uses this receptor to bind to host cells, hijack the cellular machinery, and promote its replication. If the immune system cannot contain the infection at this initial stage, the virus may advance through the lower respiratory tract and reach the pulmonary alveoli (Vieira *et al*., 2020).

As an acute respiratory infection, transmission occurs predominantly through respiratory droplets, secretions, and direct contact with infected individuals. Studies show that SARS-CoV-2 may remain suspended in the air for approximately three hours, depending on environmental conditions, and remain viable on plastic surfaces for up to 72 hours (Brito *et al*., 2020).

With regard to the clinical manifestation of infection, SARS-CoV-2 primarily affects the respiratory tract, possibly triggering respiratory failure and Acute Respiratory Distress Syndrome (ARDS). Nonetheless, Covid-19 should be considered a systemic disease, since it affects multiple organs and tissues (Mehta et al., 2020; Ribeiro et al., 2021).

In general, infection by SARS-CoV-2 induces an exacerbated inflammatory response capable of causing significant damage to the cardiovascular system, resulting in heart failure, arrhythmias, myocarditis, shock, and Takotsubo syndrome. These events may be associated both with the imbalance between high metabolic demand and low cardiac reserve and with the activation of thrombogenic processes. In the respiratory system, the disease may progress from mild flu-like illnesses to pneumonia and ARDS. Furthermore, systemic inflammation, characterized by excessive cytokine release, is associated with relevant laboratory alterations, such as elevated troponin, D-dimer, leukocytes, procalcitonin, ferritin, interleukin-6, lactate dehydrogenase, and C-reactive protein (Ribeiro et al., 2021).

Clinical progression of Covid-19 may occur over up to 16 days after a short incubation period in mild to moderate cases, and may extend up to 10 weeks in more severe situations, in which the outcome may be fatal (Vieira et al., 2020). The emergence of viral variants is also noteworthy, such as Omicron, identified in 2021, characterized by multiple mutations. In addition to this variant, Alpha, Beta, Gamma, and Delta variants remain in circulation (PAHO, 2023).

To identify SARS-CoV-2 infection, serological tests and molecular methods are used, with particular emphasis on Real-Time Polymerase Chain Reaction (RT-qPCR), considered the gold standard for viral detection because it enables real-time amplification of viral RNA. As complementary tools for clinical investigation of the disease, imaging exams such as chest X-ray and computed tomography are employed (Ribeiro *et al*., 2021).

MAIN SEQUELAE OF COVID-19

According to the Pró-Vida Program, developed by the Court of Justice of the Federal District and Territories (TJDFT, 2021), the main sequelae associated with Covid-19 include persistent fatigue, excessive tiredness, weakness, general malaise, dyspnea, breathing difficulty or shortness of breath, as well as pulmonary or renal fibrosis. Other frequently reported manifestations include headache, myalgia, cognitive impairments such as difficulty with reasoning, concentration and memory, sleep disturbances, depression, anxiety, and worsening of preexisting clinical conditions. Less frequently, alopecia, chest pain, palpitations, thrombotic events, dizziness, abdominal pain, and urinary alterations may also occur.

Corroborating these findings, Ramirez (2022) highlights that, even after clinical recovery from the acute phase of infection, it is common for patients to present, for a period exceeding 12 weeks, persistent symptoms such as intense fatigue, weakness, muscle pain, chronic cough, and loss of smell and/or taste. In the cardiovascular system, complications such as myocarditis, heart failure, arrhythmias, acute myocardial infarction, increased blood coagulation, and inflammation of the pericardium are observed.

In the respiratory system, patients may develop pulmonary stiffening, known as pulmonary fibrosis, a condition associated with dyspnea and reduced tissue oxygenation. In the renal system, episodes of acute kidney injury may occur. In the neurological domain, Covid-19 has been associated with alterations in taste and smell, persistent headache, anxiety and depression, insomnia, encephalitis, stroke, cerebral venous thrombosis, intracranial hemorrhage, mental confusion, dizziness, as well as the development of neurological syndromes such as Guillain–Barré syndrome and parkinsonian manifestations (Ramirez, 2022).

Additionally, dermatological alterations such as hair loss, blister formation, edema, and skin irritations have been described. In the gastrointestinal system, anorexia, nausea, gastroesophageal reflux, diarrhea, abdominal pain, abdominal distension, and the presence of blood in the stool may occur. Ophthalmological impairments have also been reported, including hemorrhagic or non-hemorrhagic conjunctivitis, eyelid hyperemia, optic neuritis, and alterations in corneal nerve fibers. In the endocrine system, thyroid inflammations, hyperglycemia in previously diabetic individuals, increased insulin resistance, and the onset of type 1 diabetes mellitus are noteworthy (Ramirez, 2022).

It is noteworthy that deficits in memory, language, and reasoning figure among the most prevalent post–Covid-19 sequelae, frequently associated with neurological manifestations such as headache, as well as the onset or worsening of anxiety and depression. Individuals previously infected may present neurological symptoms such as dizziness, paresthesias, and stroke, in addition to systemic manifestations such as fatigue, dyspnea, persistent inflammatory processes, weight loss, and reduced functional capacity. In the cardiovascular system, complications such as thrombosis, arterial hypertension, arrhythmias, and

myocardial infarction are reported, while metabolic and organic alterations such as diabetes mellitus, renal dysfunctions, gastroesophageal reflux, and constipation may also be present (Pinheiro, 2021).

It is believed that factors such as prolonged immobility, extended use of mechanical ventilation, and sedation during the acute phase of the disease contribute significantly to the development of long-term sequelae. Among these, gustatory deficits; dysfunctions of the musculoskeletal, cardiorespiratory, gastrointestinal, cutaneous, and urinary systems; as well as cognitive impairments, such as attention and memory deficits; and mood alterations stand out. Even in mild cases of Covid-19, persistent fatigue, dyspnea, tachycardia, loss of muscle mass, reduced functional capacity, and, in the long term, pulmonary dysfunction are observed (Leal, 2021).

HEMATOLOGICAL SEQUELAE OF COVID-19

Among the numerous sequelae associated with Covid-19, hematological alterations stand out for their high frequency and clinical relevance. In this context, hypercoagulable states are commonly described, as well as alterations in platelet, leukocyte, and erythrocyte counts. The main alterations observed in patients with more severe disease include neutrophilia, lymphopenia, prolonged prothrombin time, and elevated D-dimer levels (Ribeiro *et al*., 2021).

According to Tang *et al*. (2020), several hematological parameters have been widely used as auxiliary tools in monitoring the clinical course of patients infected by SARS-CoV-2, as they reflect both the systemic inflammatory response and the severity of infection. Among these parameters, the occurrence of leukocytosis and neutrophilia—frequently associated with the exacerbated inflammatory state—stands out, as well as the worsening of lymphocytopenia, considered an important prognostic marker in patients with Covid-19. Additionally, the development of thrombocytopenia has been recurrently described, being related to disease progression, systemic involvement, and increased risk of complications, particularly in more severe clinical cases.

It is common for patients affected by Covid-19 to present reduced total leukocyte count and, especially, circulating lymphocytes. Viral infection promotes a systemic increase in inflammatory mediators and proinflammatory cytokines, capable of triggering significant lymphopenia, defined by an absolute lymphocyte count (ALC) below 1.0×10^9/L. Beyond the quantitative reduction, morphological alterations in lymphocytes are also described, such as cellular heterogeneity, presence of lymphoplasmacytoid lymphocytes, and large granular lymphocytes, reflecting a state of exacerbated immune activation (Ribeiro *et al*., 2021).

Neutrophilia, in turn, is closely associated with cytokine release and the hyperinflammatory condition observed in Covid-19, playing a relevant role in the disease's pathophysiology. In patients admitted to intensive care units, neutrophilia may also be related to the occurrence of secondary bacterial

infections. From a morphological standpoint, neutrophils may present hyposegmented nuclei, chromatin with pro-apoptotic characteristics, and hypergranular cytoplasm, sometimes with hypogranular basophilic areas. These alterations reflect accelerated and disordered granulopoiesis, correlated with the systemic hyperinflammatory state (Ribeiro *et al*., 2021).

Another frequent finding in patients diagnosed with Covid-19 is a hypercoagulable state, evidenced mainly by elevated levels of D-dimer—a product of fibrin degradation—whose presence is associated with worse prognosis and increased mortality. It should be noted that both hospitalized patients and those under outpatient follow-up present increased risk for venous thromboembolism, and early and prolonged pharmacological thromboprophylaxis—especially with low-molecular-weight heparin—is recommended (Ribeiro *et al*., 2021).

Studies conducted with patients severely affected by Covid-19 have demonstrated a high prevalence of circulating autoantibodies in the post-infection period. A study conducted in 2021 revealed that about 50% of the patients evaluated presented approximately 15 distinct autoantibodies directed against autoantigens associated with autoimmune diseases, such as myositis and systemic sclerosis. Furthermore, approximately 25% of these individuals presented antinuclear antibodies, suggesting persistent autoimmune activation following SARS-CoV-2 infection (Figueiredo *et al*., 2021).

In addition to quantitative alterations in hematological parameters, studies have demonstrated morphological and functional modifications in different cellular populations of the immune system in patients affected by Covid-19. Among these alterations, changes in cell volume and functional profiles of monocytes stand out, especially in individuals with more severe clinical manifestations. These alterations reflect a state of exacerbated immune activation and may contribute to dysfunction of the innate immune response, favoring imbalance between inflammation and coagulation. In this context, an association of these cellular alterations with the development of hemostatic disorders, such as disseminated intravascular coagulation (DIC), is observed—a condition frequently related to worse prognosis and increased mortality in patients with Covid-19 (Tang *et al*., 2020).

Additionally, a significant increase in clot formation and in thrombotic events in patients severely affected by Covid-19 has been widely documented, configuring a systemic coagulopathy associated with viral infection. These hematological and vascular manifestations are mainly related to two central pathophysiological mechanisms: exacerbated release of proinflammatory cytokines, characterizing the so-called cytokine storm, and the direct interaction of SARS-CoV-2 with angiotensin-converting enzyme 2 (ACE2) receptors, widely expressed in endothelial cells and various tissues throughout the organism. This interaction contributes to endothelial inflammation, vascular dysfunction, and activation of the coagulation cascade, favoring thrombus formation and aggravating systemic involvement observed in the most severe cases of the disease (Tang *et al.*, 2020).

The cytokine storm consists of massive release of signaling proteins produced by immune cells and other cell types, which act as mediators of the immune response against the pathogen. However, when this response occurs in a dysregulated manner, cytokines begin to cause damage to uninfected cells and tissues, contributing to the development of persistent systemic and hematological sequelae (Figueiredo *et al*., 2021).

As a consequence of this exacerbated immunological process, severe autoimmune diseases may arise, such as Guillain–Barré syndrome, in which the immune system itself begins to attack structures of the nervous system. In the hematological context, autoimmune hemolytic anemia stands out, characterized by the production of immunoglobulins of the IgG and/or IgM type directed against antigens on the surface of erythrocytes, resulting in activation of the complement system and the reticuloendothelial system, with consequent hemolysis and hemoglobin levels below 10 g/dL (Figueiredo *et al*., 2021).

In patients affected by Covid-19, a significant impact on the hematopoietic system is also observed, with emphasis on persistent lymphopenia. In individuals who progressed to severe forms of the disease, there are reports of the development of autoimmune diseases, such as systemic lupus erythematosus. This phenomenon may be explained by oxidative stress induced by viral infections, which potentiates defects in DNA methylation mechanisms, leading to genomic hypomethylation, overexpression of the ACE2 protein, and increased viremia—favoring perpetuation of the inflammatory and autoimmune response (Figueiredo *et al*., 2021).

CONCLUSION

Covid-19, caused by the SARS-CoV-2 virus, has been consolidated as a disease with broad systemic impact, whose consequences extend beyond the acute phase of infection. Although the disease's initial mechanisms have been widely investigated, it has become increasingly evident that a significant number of recovered individuals present persistent clinical manifestations, characterizing post–Covid-19 syndrome. In this context, hematological alterations emerge as central components interlinked with different physiological systems, reinforcing the need for an integrated and in-depth approach to the topic.

In line with the proposed objective, this systematic review made it possible to investigate and describe, in a critical and organized manner, the main sequelae in the hematological system resulting from SARS-CoV-2 infection in patients recovered from the acute phase of the disease. The findings of the analyzed literature show that alterations such as lymphopenia, neutrophilia, thrombocytopenia, hypercoagulable states, prolonged prothrombin time, and elevated D-dimer levels are recurrent, especially in individuals who presented more severe clinical conditions. These alterations reflect impairment of the hematopoietic system and its close interface with the immune, cardiovascular, and inflammatory systems.

The discussed data demonstrate that these hematological dysfunctions are strongly associated with an exacerbated and dysregulated inflammatory response, mediated by excessive release of cytokines and chemokines. Although this mechanism is fundamental for viral control, its prolonged or inadequate activation contributes to tissue damage, endothelial dysfunction, activation of coagulation, and the emergence of autoimmune phenomena, such as autoimmune hemolytic anemia—corroborating the pathophysiological complexity of post–Covid-19 syndrome.

Additionally, evidence indicates that patients subjected to intensive interventions, such as invasive mechanical ventilation, present higher risk of persistent systemic sequelae, including long-lasting hematological alterations. These findings reinforce that Covid-19's impact is not limited to a single system, but results from a systemic imbalance involving multiple interdependent biological pathways.

Thus, this bibliographic review is justified in systematizing the available knowledge on post–Covid-19 hematological sequelae, contributing to understanding the role of the hematological system in clinical progression and prognosis of these patients. By integrating dispersed data from the literature, this study offers relevant scientific subsidies for clinical follow-up, planning of therapeutic strategies, and the development of future research—especially those aimed at the early identification of complications and improvement of the quality of life of affected individuals.

It is concluded, therefore, that scientific deepening on the hematological sequelae associated with Covid-19 is essential to understand the magnitude of the systemic impact of SARS-CoV-2 infection. This review not only consolidates existing knowledge but also highlights gaps that should be explored by longitudinal and multicenter studies, reaffirming its scientific relevance in the current context of health research.

REFERENCES

1. Araujo, F. A. G. da R. Usos e limites do laboratório clínico na pandemia de COVID-19: uma revisão didática [Uses and limits of the clinical laboratory in the COVID-19 pandemic: a didactic review]. Revista da Associação Médica Brasileira, São Paulo, 2020.

2. Brito, S. B. P.; Braga, I. O.; Cunha, C. C.; Palácio, M. A. V.; Takenami, I. Pandemia da Covid-19: o maior desafio do século XXI [COVID-19 pandemic: the greatest challenge of the 21st century]. Visa em Debate: Sociedade, Ciência e Tecnologia, 2020. Available at: https://docs.bvsalud.org/biblioref/2020/07/1103209/2020_p-028.pdf. Accessed on: 27 Mar. 2024.

3. Cruz, V. A. G. da. Metodologia da pesquisa científica [Scientific research methodology]. São Paulo: Pearson Prentice Hall, 2010.

4. Figueiredo, B. Q. et al. Tempestade de citocinas e desenvolvimento de doenças autoimunes como sequela da Covid-19 [Cytokine storm and development of autoimmune diseases as a sequela of COVID-19]. Research, Society and Development, v. 10, n. 11, 2021. Available at: https://rsdjournal.org/index.php/rsd/article/view/19385/17252. Accessed on: 02 Apr. 2024.

5. Guan, W. J. et al. Clinical characteristics of coronavirus disease 2019 in China. New England Journal of Medicine, Boston, v. 382, n. 18, p. 1708–1720, 2020. DOI: 10.1056/NEJMoa2002032.

6. Khalil, O. A. K.; Khalil, S. da S. SARS-CoV-2: taxonomia, origem e constituição [SARS-CoV-2: taxonomy, origin and constitution]. Revista de Medicina, 2020.

7. Lakatos, E. M.; Marconi, M. de A. Fundamentos de metodologia científica [Fundamentals of scientific methodology]. 7. ed. São Paulo: Atlas, 2010.

8. Leal, A. Sequelas e reabilitação pós-Covid-19 [Sequelae and post-COVID-19 rehabilitation]. Magnamed, 2021. Available at: https://www.inovacoesmagnamed.com.br/post/sequelas-e-reabilitacao-pos-covid-19. Accessed on: 27 Mar. 2024.

9. Lira, P. C. et al. Reabilitação e sequelas pós-Covid-19: uma revisão integrativa [Rehabilitation and post-COVID-19 sequelae: an integrative review]. In: III Congresso Internacional das Ciências da Saúde (COINTER PDVS), 2021. Available at: https://web.archive.org/web/20220112144643id_/https://cointer.institutoidv.org/smart/2021/pdvs/uploads/56.pdf. Accessed on: 02 Apr. 2024.

10. Organização Pan-Americana da Saúde (OPAS). Folha informativa sobre a Covid-19 [COVID-19 fact sheet]. 2023. Available at: https://www.paho.org/pt/covid19. Accessed on: 20 Mar. 2024.

11. Organização Pan-Americana da Saúde (OPAS). Histórico da pandemia de Covid-19 [History of the COVID-19 pandemic]. 2023. Available at: https://www.paho.org/pt/covid19/historico-da-pandemia-covid-19. Accessed on: 20 Mar. 2024.

12. Pinheiro, C. Uma doença chamada pós-Covid [A disease called post-COVID]. Veja Saúde, 2021. Available at: https://saude.abril.com.br/medicina/uma-doenca-chamada-pos-covid/. Accessed on: 27 Mar. 2024.

13. Pró-Vida. Sequelas mais comuns pós-Covid-19 e possibilidades de recuperação [Most common post-COVID-19 sequelae and recovery possibilities]. Tribunal de Justiça do Distrito Federal e dos Territórios (TJDFT), 2021. Available at: https://www.tjdft.jus.br/informacoes/programas-projetos-e-acoes/pro-vida/dicas-de-saude/pilulas-de-saude/sequelas-mais-comuns-pos-covid-19-e-possibilidades-de-recuperacao. Accessed on: 27 Mar. 2024.

14. Ramirez, G. Sequelas da Covid-19: quais são e o que fazer [COVID-19 sequelae: what they are and what to do]. Tua Saúde, 2022. Available at: https://www.tuasaude.com/sequelas-covid-19/. Accessed on: 27 Mar. 2024.

15. Ribeiro, B. R.; Barbosa, J. C. B.; Coelho, M. P. C.; Ataíde, N. X. de L. Alterações hematológicas na Covid-19: uma revisão bibliográfica [Hematological changes in COVID-19: a literature review]. 2021. Available at: https://repositorio.animaeducacao.com.br/bitstream/ANIMA/19971/1/Altera%C3%A7%C3%B5es%20hematol%C3%B3gicas%20na%20Covid-19%20-%20uma%20revis%C3%A3o%20bibliogr%C3%A1fica.pdf. Accessed on: 27 Mar. 2024.

16. Secretaria de Atenção Primária à Saúde (SAPS). Protocolo de manejo clínico do coronavírus (Covid-19) na atenção primária à saúde [Clinical management protocol of coronavirus (COVID-19) in primary health care]. Brasília, DF, 2020. Available at: https://www.unasus.gov.br/especial/covid19/pdf/37. Accessed on: 27 Mar. 2024.

17. Tang, Ning; Li, Dengju; Wang, Xiong; Sun, Ziyong. Abnormal coagulation parameters are associated with poor prognosis in patients with novel coronavirus pneumonia. Journal of Thrombosis and Haemostasis, Hoboken, v. 18, n. 4, p. 844–847, 2020. DOI: 10.1111/jth.14768.

18. Vieira, L. M. F.; Emery, E.; Andriolo, A. et al. Covid-19: diagnóstico laboratorial para clínicos [COVID-19: laboratory diagnosis for clinicians]. [S.l.: s.n.], 2020.

REALIZATION:

CNPJ: 589029480001-12
contato@aurumeditora.com
(41) 98792-9544
Curitiba - Paraná
www.aurumeditora.com