

Bridging scientific frontiers: an integrative structural biology platform for viral protein research accelerating global health solutions.

Conectando fronteiras científicas: uma plataforma integrativa de biologia estrutural para pesquisa de proteínas virais acelerando soluções em saúde global.

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Abstract:

The emerging viral diseases continue to challenge global health systems, demanding rapid and integrative scientific responses that bridge molecular understanding and translational medicine. This report analyzes the design and establishment of a multinational structural biology platform resulting from a strategic partnership between Brazil's Center for Technological Development in Health (CDTS-Fiocruz) and Chinese research institutions, particularly the Institute of Microbiology of the Chinese Academy of Sciences (IMCAS). The objective of this study is to describe the implementation of this platform as a replicable model for international scientific cooperation. By integrating cryo-electron microscopy (cryo-EM) studies and 3D computational modeling, the platform enables multiscale characterization of viral proteins from atomic to supramolecular levels. Through the synergy of structural biology, bioinformatics, and molecular dynamics simulations, this initiative provides unprecedented insights into viral morphogenesis and host-pathogen interfaces, exemplified by the structural elucidation of Chikungunya virus proteins, started in 2016 during the global Virome Project (GVP), a global initiative for scientific cooperation. As a scientific innovation, the program embodies science diplomacy, establishing bilateral technology transfer frameworks and researcher exchange programs that strengthen pandemic preparedness. By uniting advanced methodologies with political-scientific cooperation, this integrative platform reinforces Brazil's strategic position as a leader in collaborative structural virology and translational medicine.

Keywords: Structural biology, Cryo-electron microscopy, Viral proteins, NMR spectroscopy, Brazil-China collaboration.

Resumo:

As doenças virais emergentes continuam a desafiar os sistemas globais de saúde, exigindo respostas científicas rápidas e integrativas que conectem o entendimento molecular à medicina translacional. Este trabalho analisa a concepção e implementação de uma plataforma multinacional de biologia estrutural, resultado de uma parceria estratégica entre o Centro de Desenvolvimento Tecnológico em Saúde (CDTS-Fiocruz), no Brasil, e instituições de pesquisa chinesas, especialmente o Instituto de Microbiologia da Academia Chinesa de Ciências (IMCAS). O objetivo é descrever essa plataforma como um modelo replicável de cooperação científica internacional. Ao

integrar estudos de microscopia crioeletrônica (cryo-EM) e modelagem computacional tridimensional, a plataforma permite a caracterização multiescalar de proteínas virais, desde o nível atômico até o supramolecular. Por meio da sinergia entre biologia estrutural, bioinformática e simulações de dinâmica molecular, essa iniciativa fornece novos insights sobre a morfogênese viral e as interfaces hospedeiro-patógeno, exemplificados pela elucidação estrutural de proteínas do vírus Chikungunya, iniciada em 2016 no contexto do Global Virome Project. Como inovação científica, o programa incorpora a diplomacia científica, estabelecendo estruturas bilaterais de transferência de tecnologia e programas de intercâmbio de pesquisadores que fortalecem a preparação para pandemias. Ao combinar metodologias avançadas com cooperação político-científica, essa plataforma integrativa reforça a posição estratégica do Brasil como líder em virologia estrutural colaborativa e medicina translacional.

Palavras-chave: *Biologia estrutural; Microscopia crioeletrônica (cryo-EM); Proteínas virais; Espectroscopia RMN; Cooperação científica Brasil-China.*

1. Introduction

The increasing threat of emerging viral diseases demands rapid, multidisciplinary, and collaborative scientific efforts to elucidate viral protein structures and translate these insights into therapeutic innovations. This report analyzes the implementation of an advanced research platform designed to accelerate solutions in global health through the integration of nuclear magnetic resonance (NMR), cryo-electron microscopy (cryo-EM), and sophisticated 3D imaging modalities. The "platform" is defined as an integrated ecosystem of physical infrastructure, standardized computational pipelines, and bilateral governance protocols (detailed in Figure 3). The project, developed by CDTs-Fiocruz in collaboration with the Federal University of Rio de Janeiro (UFRJ), establishes a structural biology framework that extends beyond individual research efforts and strengthens institutional cooperation (ABC, 2025).

The two centers will conduct coordinated research on Zika virus, yellow fever virus, dengue virus, chikungunya virus, influenza viruses, and Oropouche fever - a dengue-like disease historically restricted to the Amazon region but now increasingly reported in major Brazilian urban centers. This research agenda encompasses multidisciplinary investigations in immunology, structural biology, epidemiology, and the development of therapeutic antibodies, aiming to strengthen translational responses to emerging and re-emerging viral threats.

The strategic partnership with BGI and ZTE-ICT will provide both centers with robust technological infrastructure, particularly in high-throughput genomic sequencing and advanced data communication systems. This integrated technological framework will enhance genomic surveillance capacity, real-time epidemiological monitoring, and large-scale molecular data analysis, thereby reinforcing institutional preparedness for epidemic response (Fiocruz, 2025).

Distinctive in its integrative approach, the platform bridges atomic- and mesoscale insights, from detailed cryo-EM studies of virus particles to high-resolution visualization of viral assemblies at IMCAS and Sutekh, China. This multiscale framework facilitates the

characterization of emerging viral proteins and arboviral envelopes from Zika and Chikungunya viruses and serves as a model for technology transfer and scientific diplomacy in the Global South (Fundação Oswaldo Cruz-CDTS, 2025a).

2. Development

2.1 Platform Capabilities and Innovations

Drawing on cumulative expertise from CDTS-Fiocruz and IMCAS, the platform achieves high-resolution characterization of complex viral proteins. A landmark result of this collaboration was the structural elucidation of the interaction between the human MXRA8 receptor and the Chikungunya virus (Figure 2), which provided critical data for understanding viral entry mechanisms (Fundação Oswaldo Cruz-CDTS, 2025b). The platform leverages complementary cryo-EM studies conducted through Sino-Brazilian partnerships, facilitating atomic-level insight into viral-host protein interfaces vital for antiviral drug design.

Advanced structural techniques, such as cryo-EM and crystallography modeling, extend the structural narrative into physiologically relevant contexts, enabling comprehensive viral morphogenesis visualization. As illustrated in Figure 1, the platform engages sophisticated bioinformatic pipelines that merge experimental data and molecular docking and molecular dynamics simulations. This workflow allows for the quantification of protein conformational fluctuations and the identification of targetable regions for rational drug design (Figure 1, Middle and Right panels), thereby empowering rapid antiviral candidate assessment for translational applications (Fundação Oswaldo Cruz-CDTS, 2025c).

2.2 The Vital Role of UFRJ and CDTS-Fiocruz in Brazil's Scientific Ecosystem

At the core of Brazil's biomedical research infrastructure, the Federal University of Rio de Janeiro (UFRJ) and the Center for Technological Development in Health (CDTS-Fiocruz) support a network of cutting-edge laboratories dedicated to structural virology, diagnosis, basic science, and drug development. These units facilitate recombinant protein technology, high-resolution spectroscopy, and bioinformatics. By maintaining a concentrated focus on flavivirus research, this institutional ecosystem provides essential data for global efforts to control viral epidemics (Fundação Oswaldo Cruz-CDTS, 2025d).

The CDTS-Fiocruz serves as a strategic hub for health innovation, implementing frameworks that facilitate technology sharing and joint research programs. The institution orchestrates programs bridging molecular tools, bioinformatics, and large-scale genomic

technologies. A concrete example of this implementation is the recent acquisition and integration of Chinese-origin high-throughput sequencers, a methodological advance that significantly bolsters Brazil's genomic surveillance and response capabilities (Fundação Oswaldo Cruz-Fiocruz, 2025a).

Figure 1: Bioinformatic integration of molecular dynamics and docking studies.

An Integrated Workflow: From Atomic to Mesoscale Resolution

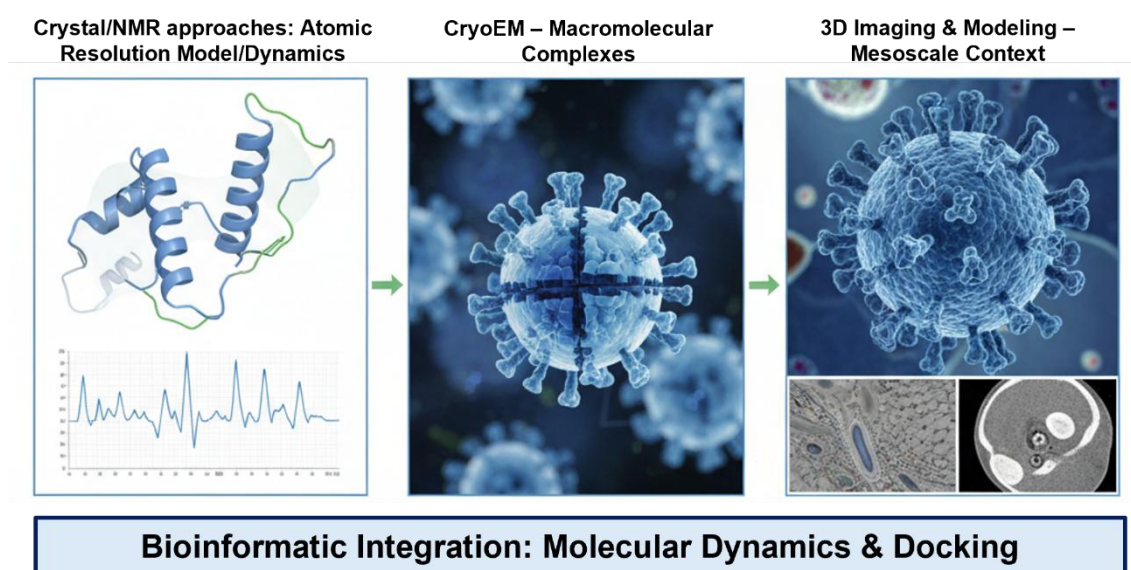


Figure caption: Left panel: Representative protein structure with associated molecular dynamics profile illustrating conformational fluctuations. Middle panel: Three-dimensional model of a viral particle, highlighting targetable regions for drug binding. Right panel: Detailed structural visualization of the virus, including microscopy and tomography images, integrating molecular and cellular perspectives for rational drug design. (illustrative I.A. figures). Source: Author.

2.3 Governance and Strategic Collaboration: Institutional Leadership

The coordination of CDTS-Fiocruz has established Brazil as a key node in international viral research networks. These agreements extend beyond formal administrative functions, serving as operational frameworks that support the establishment of bilateral infectious disease research centers and enable coordinated surveillance and cross-platform technical development (Fundação Oswaldo Cruz-Fiocruz, 2025b).

The partnership is further strengthened by the adoption of robust global scientific networks and data-sharing paradigms, which are essential for accelerating epidemic intelligence and vaccine development. This synergy between Brazilian institutional leadership and international research priorities exemplifies how science diplomacy can be operationalized to drive pandemic preparedness. By aligning political and scientific agendas, collaboration

ensures that the research remains relevant to public health priorities and facilitates smooth technology transfer (Morel, 2025).

2.4 Operational Structure of the Brazil–China Scientific Cooperation

To provide clarity regarding the cooperation summarized in Figure 3, the operational framework of the Brazil–China structural biology platform is detailed below.

The platform operates through a clearly defined division of roles among its partner institutions. The Center for Technological Development in Health (CDTS-Fiocruz), in Brazil, assumes strategic coordination of the platform, implementing governance protocols and Memoranda of Understanding (MoUs), integrating molecular tools, bioinformatics pipelines, and genomic technologies, overseeing the installation and operationalization of high-throughput sequencing systems, and aligning research activities with Brazilian public health priorities. Complementing this effort, the Federal University of Rio de Janeiro (UFRJ) maintains specialized laboratories dedicated to structural virology, diagnosis, and drug development, while advancing recombinant protein production, high-resolution spectroscopy, structural analysis, and computational modeling workflows.

On the Chinese side, the Institute of Microbiology of the Chinese Academy of Sciences (IMCAS) executes high-resolution cryo-electron microscopy studies, performs structural refinement of viral proteins, participates in bilateral infectious disease research centers, and integrates within CAS-TWAS collaborative excellence programs. The Southern University of Science and Technology (SUSTech), in Shenzhen, provides critical support for cryo-EM infrastructure, contributes to atomic-level visualization of viral assemblies, and engages in technical collaboration for structural refinement. Additional partner institutions — including the Shenzhen Popular Hospital, the Beijing Genomics Institute (BGI), the Chinese Academy of Sciences (CAS), and the Brazilian Ministry of Science, Technology and Innovation (MCTI) — contribute to regulatory alignment, coordinated funding, genomic technology expansion, and infectious disease surveillance networks.

The activities conducted in Brazil focus on recombinant viral protein production, nuclear magnetic resonance (NMR) spectroscopy, bioinformatics integration and molecular docking, molecular dynamics simulations, the installation and integration of Chinese-origin high-throughput sequencers, and the coordination of governance structures and regulatory alignment. Together, these activities strengthen national structural biology capacity and genomic surveillance systems.

In China, the activities include high-resolution cryo-electron microscopy, visualization of viral particles at supramolecular resolution, structural characterization of viral-host protein interfaces, technical training of Brazilian researchers, and integration of Brazilian projects into advanced cryo-EM facilities. This complementary infrastructure model reduces duplication and maximizes technical efficiency.

The scientific expertise integrated within the cooperation spans structural virology, cryo-electron microscopy, nuclear magnetic resonance spectroscopy, molecular dynamics simulations, genomic surveillance, bioinformatics, and science diplomacy and governance. This multidisciplinary integration enables the platform to operate across atomic, molecular, and supramolecular scales.

The Memoranda of Understanding formalized between Fiocruz and Chinese institutions function as legal frameworks for bilateral cooperation, instruments for establishing joint infectious disease research centers, mechanisms for technology sharing, and structures for coordinated surveillance and cross-platform technical development, thereby ensuring institutional continuity beyond individual projects.

Technology transfer within the platform occurs through the installation of Chinese-origin high-throughput sequencing systems in Brazil, shared cryo-EM workflows, standardization of computational pipelines, researcher mobility programs, and joint workshops and technical training initiatives. This structured transfer strengthens Brazil's response capacity to emerging viral threats.

Scientifically, cooperation enables multiscale viral protein characterization, facilitates antiviral drug target identification, expands structural biology capacity in the Global South, and supports pandemic preparedness through integrated infrastructure. Politically, the initiative aligns Brazilian and Chinese science and technology agendas, establishes regulatory harmonization frameworks, strengthens bilateral diplomatic relations through science diplomacy, and serves as a replicable governance model for international health cooperation.

2.5 Brazil-China Researcher Exchange: Building Bridges for Mutual Scientific Advancement and Pandemic Preparedness

2.5.1 Institutional Human Resource Development: The Brazil-China Exchange Program

A key component of this collaboration is a structured researcher exchange program between Brazil and China. Through training programs and joint workshops, this initiative enables skill

Figure 2: Structural and functional representation of the interaction between human hMXRA8 and the Chikungunya virus (CHIKV) E1–E2 glycoproteins.

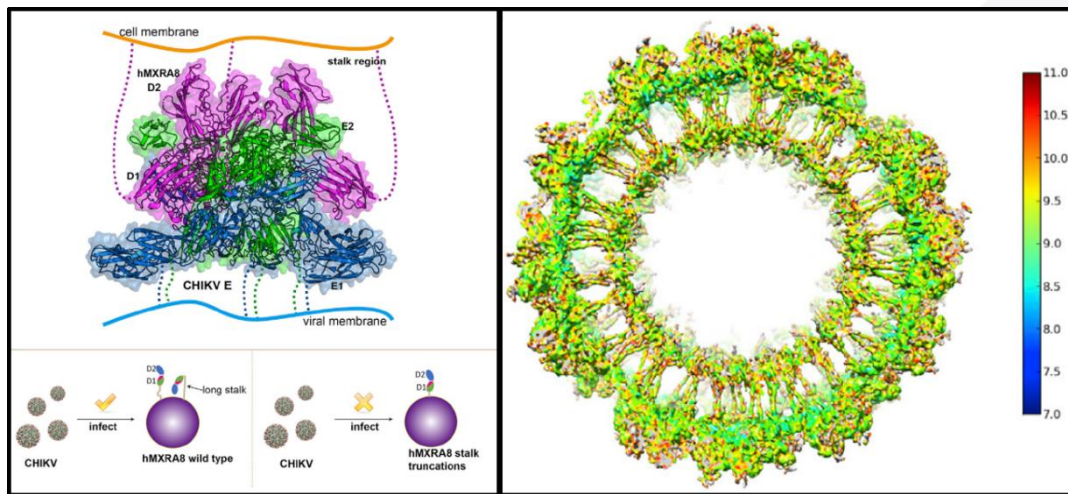


Figure caption: Left: The structural model shows the organization of hMXRA8 domains (D1–D2) and their interface with viral proteins E1 and E2, positioned between the host-cell and viral membranes. Below, schematic diagrams illustrate how the full-length hMXRA8 stalk enables CHIKV entry, whereas mutations or truncations in this region inhibit infection. Right: Structural variability map (color scale 7.0–11.0 Å) highlighting conformational flexibility across the viral surface and local differences in organization. Source: Fundação Oswaldo Cruz-CDTS, 2025b).

development in advanced technologies, including synchrotron radiation and structural proteomics. By institutionalizing these exchanges, the platform develops a specialized workforce of specialists' adept in leveraging multidisciplinary approaches for viral disease research (Fundação Oswaldo Cruz-CDTS, 2025b). Reciprocal academic visits serve as a strategic mechanism to foster technical trust and the co-development of innovative methodologies and therapeutic strategies. This systematic exchange creates a dynamic workforce capable of responding to pandemics with agility, ensuring institutional resilience through shared expertise and standardized protocols (Song *et al.*, 2019).

2.5.2 The Strategic Framework of Political-Scientific Integration

The sustainability of this scientific synergy relies on the strategic integration of political frameworks with research agendas. Bilateral agreements between Brazil's Ministry of Science, Technology and Innovation (MCTI) and Chinese counterparts formalize cooperation through coordinated funding, regulatory alignment, and intellectual property agreements. Governing committees and joint task forces ensure that research projects remain strictly aligned with public health priorities, effectively operationalizing science diplomacy through technological advancement (Song *et al.*, 2019). This governance nexus creates an environment conducive to

technology transfer and accelerates translational research, positioning Brazil and China as strategic partners in global health innovation. Such integrated governance serves as a replicable model for international scientific collaboration in responding to emerging viral threats (The World Academy of Science, 2022).

2.5.3 Global Scientific Collaboration and Institutional Impact

Beyond bilateral ties, the platform engages with international research leaders in Europe and North America, fostering multidisciplinary consortia. These global connections enhance Brazil's structural biology competence and expand the regional impact of its health sciences through institutional cooperation. A critical component of this capacity building has been the strategic expansion of access to world-class facilities in China for the Brazilian scientific community. This institutional bridge is essential for sustaining Latin America's scientific growth and ensuring international competitiveness in the structural biology landscape (IMCAS, 2025).

3. Conclusion

The structural biology platform established between CDTS-Fiocruz and Chinese institutions provides a functional model for multinational research cooperation. By integrating complementary infrastructures—NMR and recombinant protein production in Brazil, cryo-EM at IMCAS and SUSTech—the initiative enables multiscale analysis of viral proteins critical for antiviral development.

The collaboration's success, illustrated by the structural characterization of Chikungunya virus glycoproteins, highlights the importance of formal governance structures, including bilateral MoUs and institutionalized researcher exchange programs.

For Brazil, this partnership has strengthened domestic capacity in structural biology and genomic surveillance while ensuring sustained access to advanced technologies. More broadly, the experience derived from this collaboration yields generalizable lessons for similar international science and technology initiatives.

Key among these is the finding that success depends not only on infrastructure investment but also on the deliberate alignment of governance mechanisms — including bilateral MoUs, structured researcher exchange programs, and coordinated funding streams — with clearly defined public health priorities.

Figure 3: Diagram illustrating the scientific interchange network between Brazil and China, highlighting its structure and governance.

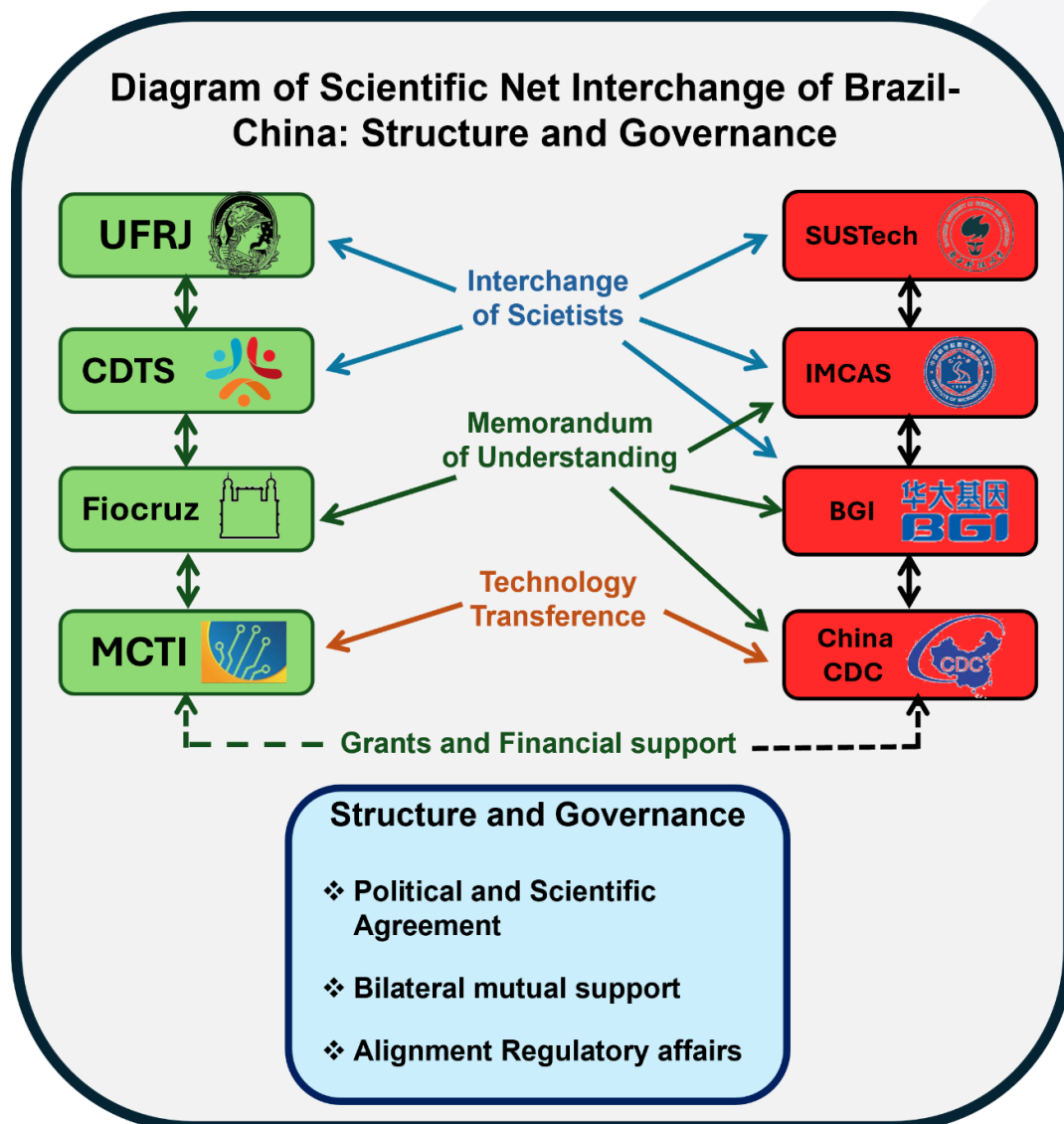


Figure caption: Left: Brazilian institutions (UFRJ, CDTS, Fiocruz, MCTI); Right: Chinese institutions (SUSTech, IMCAS, BGI, China CDC). Arrows represent major axes of collaboration, including scientist exchange, memoranda of understanding, technology transfer, and financial support. At the bottom, the core governance principles sustaining the partnership are summarized: political and scientific agreements, bilateral mutual support, and regulatory alignment. Source: Author.

Furthermore, the integration of complementary technological capabilities across national borders, as demonstrated by the Brazil-China model, reduces redundancy and accelerates translational outcomes. Platforms of this nature, grounded in both scientific alignment and diplomatic frameworks, therefore represent a strategic investment for responding to emerging viral threats and offer a replicable template for multinational cooperation in global health.

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6. Authors' Contributions

Autor 1: concepção do estudo, análise de dados, redação inicial do manuscrito, revisão crítica do conteúdo intelectual e orientação metodológica, coleta de dados, tabulação estatística, revisão final do manuscrito, apoio na revisão bibliográfica e elaboração das tabelas/figuras.

7. Declaration of conflict of interest

I have no conflicts of interest of a financial, commercial, political, academic, or personal nature that could inappropriately influence the preparation, analysis, interpretation, or publication of this manuscript.