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REVIEW ARTICLE

Enhancing Biomedical Research Through Strategic Funding: A Comprehensive Review

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Abstract

Background and Aims: Biomedical research play a vital role in driving health innovations, but the intricate funding landscape presents significant hurdles for researchers. This review seeks to explore the significance of funding in biomedical research, the obstacles encountered in obtaining such funding, and the economic ramifications of these investments. **Methods:** A narrative review was performed through an extensive literature search in databases such as PubMed, Scopus, and Web of Science from December 1 to 10, 2024. The search targeted peer-reviewed articles, government reports, and publications related to biomedical research funding, using keywords like "biomedical research funding," "grant application processes," and "diversity in research funding." **Results:** The findings underscore the essential role of funding in promoting research productivity and innovation. Major challenges identified include a complicated grant application process, insufficient financial support for underrepresented groups, and a lack of transparency in funding mechanisms. Additionally, while there are signs of positive returns from investing in biomedical research, thorough analyses of the economic impacts are still lacking. **Conclusions:** The review highlights the necessity for strategic reforms to improve collaboration and transparency in funding mechanisms. Tackling the identified challenges is crucial to strengthen biomedical research efforts and ensure a variety of perspectives in addressing the urgent health issues facing society. Improved funding strategies can lead to better research outcomes and advancements in public health.

Keywords: Biomedical research, funding, grant application, economic impact, diversity, transparency

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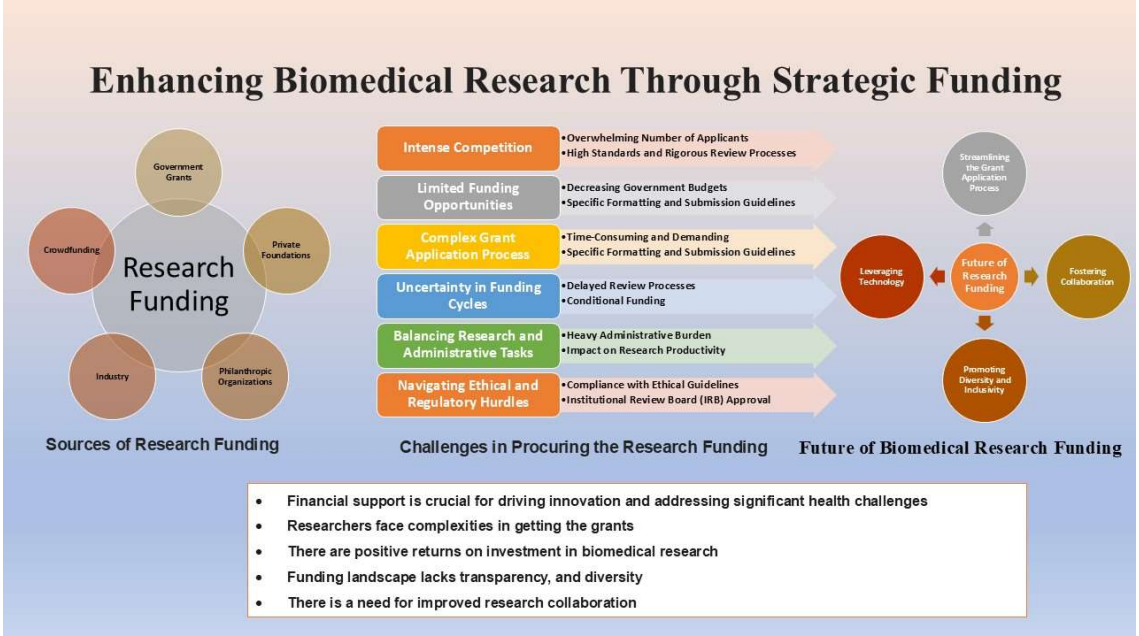
Graphical Abstract



Key Highlights

- Financial support is crucial for driving innovation and addressing significant health challenges
- Researchers face complexities in getting the grants
- There are positive returns on investment in biomedical research
- Funding landscape lacks transparency, and diversity
- There is a need for improved research collaboration

Introduction

In the field of health and medicine, biomedical research is fundamental for driving innovation and progress, essential for enhancing our understanding of human health and creating effective treatments. Research funding refers to the financial backing typically obtained through a competitive application process to support scientific studies [1]. This funding is vital for tackling some of the most pressing health challenges we face today, including chronic diseases like diabetes and cancer, as well as emerging global health threats such as epidemics and pandemics [2]. The influence of biomedical research is clear in the creation of groundbreaking therapies, life-saving drugs, and the swift development of vaccines, particularly highlighted during the COVID-19 pandemic, where scientific responsiveness and funding support enabled an unprecedented and timely vaccine rollout [3]. Additionally, funding programs significantly boost research productivity, leading to about one more published article each year. Funded researchers also enjoy greater visibility and impact, as shown by increased citation counts and altmetric scores [4]. The ever-evolving nature of biomedical research requires substantial financial resources, and the success of these efforts largely depends on access to consistent and robust funding [5,6].

However, despite its vital importance, the funding landscape for

biomedical research is becoming more intricate and competitive [7]. Researchers frequently encounter challenges in securing the necessary funding, including a complicated grant application process and limited resources allocated for innovative projects [8]. There is also a rising concern about the insufficient financial support for underrepresented groups and early-career researchers, which ultimately restricts the diversity of viewpoints crucial for tackling complex health issues. Furthermore, while the significance of funding is widely recognized, there is often a lack of transparency and clarity in the funding mechanisms [9].

There are still significant gaps in our understanding of the economic impact of investing in biomedical research. While previous studies suggest that these investments yield positive returns [10], a thorough examination of how funding affects innovation outcomes and public health metrics is still necessary. Additionally, there is a lack of empirical evidence demonstrating how diversity within research teams influences scientific progress and the success of research proposals.

This review intends to highlight the critical role of funding in biomedical research by delving into the complexities and challenges that the researchers encounter when seeking financial support, the economic ramifications of these investments, and the pressing need for improved collaboration and transparency in funding processes. By reviewing existing literature, this analysis aims to offer a well-rounded perspective on the funding landscape, pinpoint essential areas for enhancement, and ultimately encourage strategic reforms that will strengthen biomedical research initiatives to address the changing health challenges faced by society.

Methodology

This narrative review aims to explore different aspects of funding mechanisms, the challenges researchers encounter, and the economic effects of investments in this area. A thorough literature search was performed using databases like PubMed, Scopus, and Web of Science from December 1st to 10th, 2024. The search encompassed peer-reviewed articles, government reports, and publications from leading research organizations that concentrate on funding for biomedical research. Specific keywords such as "biomedical research funding," "grant application processes," "funding challenges," "economic impact of research," and "diversity in research funding" were employed to find relevant materials.

The inclusion criteria targeted studies published in the last twenty years that examine funding sources (government, private sector, philanthropic) and their effects on biomedical research. Additionally, studies addressing funding challenges and diversity issues in grant applications were included. Articles that did not primarily focus on biomedical research and opinion pieces lacking substantial data were excluded.

The extracted data encompassed findings related to various funding sources, challenges in securing funding, and the economic impact of funding on biomedical research. Key themes and trends were identified across the literature to facilitate a comprehensive understanding of the funding landscape. Thematic analysis was employed to categorize the identified

challenges and implications of funding into coherent sections.

Results and Discussion

Complexities of Biomedical Research

Biomedical research is an intricate and demanding field characterized by the time-consuming nature of scientific discovery [11,12]. Transformative breakthroughs take time to happen; they require years, if not decades, of rigorous investigation and testing. This multi-stage process often encompasses basic research, clinical trials, and the transition to market-ready solutions [13]. Funding for biomedical research is drawn from a diverse array of sources. Government agencies, such as the National Institutes of Health (NIH) and the National Science Foundation (NSF), allocate substantial budgets to support innovative research initiatives. The NIH primarily invests its nearly $48 billion budget in medical research benefiting the American population. A significant portion of this funding, around 83%, is distributed through competitive grants to over 300,000 researchers across the United States (U.S.). Approximately 11% of the budget supports research conducted by NIH scientists in their laboratories, while the remaining 6% is allocated to administrative and operational expenses [14]. The NSF supports approximately 25% of all federally funded basic research conducted by U.S. colleges and universities. With an annual budget of roughly $9.9 billion (fiscal year 2023), the NSF plays a crucial role in advancing scientific discovery [15]. Private-sector investments, including pharmaceutical companies and biotechnology firms, play a crucial role, particularly in the later stages of research, where significant capital is needed to bring products to market. Non-profit organizations and philanthropic contributions also represent key funding avenues, often targeting specific diseases or health conditions. Despite the presence of these various funding sources, the landscape of biomedical research needs to be revised. Researchers often need help to secure the funding necessary for their projects, which can stifle creativity and slow the pace of progress (Figure 1).

Figure 1: Sources of Research Funding

Challenges in Securing Funding

One of the primary challenges in the biomedical research funding landscape is the highly competitive grant application process [16]. Researchers are frequently faced with numerous applicants vying for a limited pool of resources [17]. For example, there has been fierce competition for research funding in China, which is especially difficult for early-career scientists. In 2024, there was a massive jump in applications, more than 380,000 overall, up 26% compared with last year. Only 13% of those were successful, compared with 16% in 2023 [18].

The review process can be quite challenging, demanding a lot of time and effort to satisfy strict requirements while showcasing the potential impact and feasibility of the proposed research (Figure 2). Additionally, funding levels often need to be increased to fully support innovative projects. Many grants only provide partial funding for research proposals, forcing researchers to look for extra resources to fill the financial gaps. This situation puts significant pressure on research teams and may deter young scientists and underrepresented groups from taking on ambitious projects. The issue of diversity in research funding is particularly urgent. Underrepresented groups and early-career researchers may struggle to navigate the complicated landscape of funding opportunities, which often results in a lack of diverse perspectives in biomedical research. Committing to diversity in funding is not just a moral obligation but also a crucial factor in promoting new ideas and comprehensive solutions [19]. Diverse teams contribute unique experiences and viewpoints that foster innovation and a deeper understanding of health challenges.

Figure 2. Challenges in procuring the research funding

Economic Impact of Research Funding

The economic implications of funding biomedical research extend far beyond improved health outcomes. The return on investment in this field is significant, with research yielding substantial economic benefits. According to the NIH, every dollar invested in biomedical research generates approximately $2.70 in economic returns [20]. This statistic underscores the rationale for continued public investment in research, as government appropriations directly impact the capacity of researchers to explore novel ideas and translate them into practical applications. Funding for biomedical research also contributes to job creation and economic growth. As research institutions expand and new projects emerge, they generate employment opportunities for scientists, technicians, and support staff, thereby stimulating local economies.

Additionally, successful research initiatives can lead to the establishment of new companies and industries, particularly in biotechnology and pharmaceuticals, further driving economic development. As we navigate an era characterized by unprecedented health threats and scientific advancements, it is crucial to prioritize funding in biomedical research not only for immediate health benefits but also for long-term economic sustainability [21]. Investments in research are essential to position nations as leaders in scientific innovation and to ensure global competitiveness.

Funding Organizations

In the realm of biomedical research, securing adequate funding is essential for driving innovation and advancing scientific inquiry. Various organizations play a pivotal role in providing this support, and they can be broadly categorized into government agencies, private foundations, and other organizations (Table 1). Starting with government agencies, the National Institutes of Health (NIH) in the USA stands out as the world's largest public funder of biomedical research, steering substantial resources towards understanding health and disease. Complementing the NIH, the National Science Foundation (NSF) also provides critical funding across a wide range of scientific research areas, including biomedical and health-related fields. Over in the UK, the Wellcome Trust operates as a global charitable foundation dedicated to supporting biomedical research both within the UK and internationally (Table 1). The Medical Research Council (MRC), another UK agency, is explicitly focused on funding medical and health research initiatives.

In Europe, the European Research Council (ERC) offers competitive funding for excellent frontier research across various scientific disciplines. Additionally, the Canadian Institutes of Health Research (CIHR) is the federal agency responsible for funding health research in Canada, ensuring a commitment to advancing knowledge in the field.

China has been spearheading research and publications in the past couple of decades and has achieved the 2nd rank globally after the U.S. [22,23]. Increased research funding by the Chinese government significantly influences this substantial improvement in its ranking. There has been a consistent increase in funding for science and technology, with a 10% increase in 2024 compared to the previous year. This includes GBP 10.7 billion for basic research in 2024 [24]. The National Natural Science Foundation of

China (NSFC), based in Beijing, oversees several programmes that provide funding through competitive grants, which received US$5 billion in funds in 2024. China also has international cooperation agreements with other countries, such as the EU, to support collaborative research projects [25].

In India, the Indian Council of Medical Research (ICMR) serves as the apex body for formulating, coordinating, and promoting biomedical research. The Department of Biotechnology (DBT) in India also plays a significant role in promoting biotechnology research and development, complemented by the Department of Science and Technology (DST), which funds a wide range of scientific research, including in biomedical and health-related spheres. The Council of Scientific and Industrial Research (CSIR) is another key player, providing support for research across various fields, including biomedical sciences (Table 1).

Recognizing the breadth of funding sources, we must also consider private foundations. The Bill & Melinda Gates Foundation is a major global philanthropic entity, funding an array of health and development programs aimed at improving lives across the globe. In the USA, the Howard Hughes Medical Institute (HHMI) is a non-profit medical research organization that supports biomedical research and science education, contributing significantly to advancements in these fields. The Kavli Foundation is another noteworthy private entity that invests in scientific research across disciplines like astrophysics, neuroscience, and nanoscience.

Table 1. Major Global Research Funding Organizations

Organization	Country	Focus Areas	Website
National Institutes of Health (NIH)	USA	Biomedical and health research	https://www.nih.gov/
National Science Foundation (NSF)	USA	Biomedical and health research	https://www.nsf.gov/
Bill & Melinda Gates Foundation	USA	Global health and development	https://www.gatesfoundation.org/
Howard Hughes Medical Institute (HHMI)	USA	Biomedical research and science education	https://www.hhmi.org/
European Research Council (ERC)	EU	Frontier research across all scientific disciplines	https://erc.europa.eu/homepage
Medical Research Council (MRC)	UK	Biomedical and health research	https://www.ukri.org/councils/mrc/
Wellcome Trust	UK	Biomedical and health research	https://wellcome.org/

Canadian Institutes of Health Research (CIHR)	Canada	Health Research	https://cihr-irsc.gc.ca/e/193.html
World Health Organization (WHO)	Switzerland	Health Research and Programs	https://www.who.int/
National Natural Science Foundation of China (NSFC)	China	Science and Technology	https://www.nsfc.gov.cn/
Department of Biotechnology (DBT)	India	Biotechnology research and development	https://dbtindia.gov.in/
Indian Council of Medical Research (ICMR)	India	Biomedical research	https://www.icmr.gov.in/
Department of Science and Technology (DST)	India	Science and technology research, including health sciences	https://dst.gov.in/
Council of Scientific and Industrial Research (CSIR)	India	Scientific and industrial research, including medical research	https://www.csir.res.in/
Tata Trusts	India	Philanthropic funding for various fields, including health and medical research	https://www.tatatrusts.org/

Additional organizations that fund global health initiatives include the World Health Organization (WHO), which allocates resources toward health research and programs aimed at improving health outcomes worldwide. The American Cancer Society and the Alzheimer's Association are prominent organizations that provide funding for specific disease research and patient support programs, focusing efforts on advancing treatments and improving the quality of life for affected individuals.

Many public and private organizations are dedicated to offering financial support for biomedical and healthcare research. The specific funding opportunities can differ significantly based on the research area, the researcher's location, and other contextual factors. Thelwall et al. discussed various aspects of research funding and emphasized the need to take these aspects into account when quantitatively assessing the value of research funding. They recommended that organizations gathering funding data should incorporate these aspects into their data collection methods. When comparing funding sources or assessing the impact of funding, it is essential to consider as many

relevant aspects as possible to ensure fair evaluations [12].

Publication and dissemination plan for research funded by government or philanthropic agencies are crucial to ensure the public benefits from the investment. These plans outline how research findings will be shared with the scientific community and the broader public. The plans typically include details on the types of publications (e.g., journal articles, conference presentations, reports), target audiences, and dissemination channels (e.g., websites, social media, public outreach events). Clear and explicit policies regarding these plans help to ensure transparency and accountability in research funding. In the USA, the recommendation for open access to federally funded research has gained significant traction [26]. This means that research findings would be freely available to the public, potentially accelerating scientific progress and benefiting society. Similarly, making research data publicly accessible can facilitate secondary research and meta-analyses, leading to new insights and discoveries. While open access policies have numerous benefits, there are also challenges to consider. For example, ensuring the quality and integrity of research data while making it publicly accessible requires careful planning and implementation. Additionally, concerns about intellectual property rights and potential misuse of data need to be addressed.

Scientific and professional associations like the Indian Orthopaedics Association (IOA) and Indian Medical Association (IMA) can play a vital role in fostering research by offering grants to researchers working in specific specialties or on relevant topics [27]. These associations possess a deep understanding of the field's challenges and priorities, enabling them to strategically allocate funds to projects that address critical needs. By supporting research, these associations not only advance scientific knowledge but also contribute to improving patient care, developing innovative treatments, and enhancing the overall quality of healthcare.

Agile Funding Mechanisms

The COVID-19 pandemic has clearly shown the need for flexible and responsive funding mechanisms in biomedical research. The quick development and rollout of vaccines against the virus demonstrated the effectiveness of targeted investments. Organizations, governments, and private entities collaborated to allocate resources rapidly, leading to record-breaking timelines for vaccine development. This experience underscores the necessity of establishing adaptable funding frameworks that can quickly respond to emerging health threats. Policymakers and funding agencies should focus on maintaining ongoing investment in biomedical research that supports both new and experienced scientists, ensuring that essential resources are available when crises occur. Additionally, creating resilient funding strategies will enable a proactive stance toward future health emergencies [28,29]. By cultivating an environment where researchers can quickly mobilize their efforts, we can enhance our preparedness for unforeseen challenges, minimizing potential harm to public health and promoting swift recovery.

Collaboration Between Public and Private Sectors

A key element in securing funding for biomedical research is the collaboration

between the public and private sectors [30,31]. Public funding lays the groundwork for exploratory studies that investigate new ideas and concepts. However, advancing these ideas to market readiness often necessitates private-sector involvement, where substantial capital is required for later-stage development. These partnerships can create a synergistic effect, accelerating the research and development process while ensuring that the most promising scientific ideas receive the resources they need to thrive. Collaborative models, like public-private partnerships, have proven effective in various therapeutic areas and can be adapted to stimulate innovation in other medical fields [32]. A prominent example is the collaboration that led to the development of COVID-19 vaccines. Governments worldwide teamed up with pharmaceutical companies, providing funding and support that enabled swift progress from research to distribution. Such collaborations not only yield successful results but also demonstrate how combining the strengths of both sectors can enhance the overall impact of biomedical research efforts.

Transparency and Accountability

In addition to collaboration, there is a crucial need for transparency and accountability in how research funds are allocated. Stakeholders must ensure that financial resources are distributed fairly, based on scientific merit rather than personal connections or biases. Transparency in funding processes not only enhances the integrity of research but also fosters public trust, which is vital for securing further support for biomedical initiatives. Clear criteria and guidelines for fund allocation will ensure that researchers from diverse backgrounds have equal opportunities to compete for support. Establishing and upholding ethical standards within the funding process will build confidence in the system, encouraging more individuals and organizations to invest in biomedical research. Furthermore, regular reporting and assessment of the outcomes and impacts of funded research projects can help illustrate the effectiveness of these investments [33]. This practice will provide stakeholders with valuable insights into the progress made and will serve as an important feedback loop for refining funding processes and structures over time.

Tips for Grant Application Success

Perils, pitfalls, and recommendations for young researchers, for making their grant applications a success is summarized in Table 2.

Table 2. Perils, Pitfalls, and Recommendations for Young Researchers

Perils and Pitfalls	Recommendations
Lack of clarity and focus	Develop a strong research question and hypothesis by **c**learly articulating the project's significance and innovation.
Inadequate budget justification	Provide detailed and realistic cost estimates by **j**ustifying each expense and demonstrate value for money.
Weak writing and communication	Seek feedback from mentors and colleagues. Proofread carefully and ensure the proposal is well-written and easy to understand.
Insufficient preliminary data	Conduct pilot studies or gather preliminary data to support the proposed research by demonstrating feasibility and preliminary success.
Inadequate mentorship and support	Seek guidance from experienced mentors and **b**uild a strong support network within the institution and field.
Not understanding the funding agency's priorities	Thoroughly review the funding agency's guidelines and priorities; and **t**ailor the proposal to their specific interests.
Underestimating the time commitment	Allocate sufficient time for proposal development and submission by **s**tarting early and allowing ample time for revisions and feedback.
Not addressing potential risks and challenges	Identify potential obstacles and develop mitigation strategies by demonstrating a realistic understanding of the project's challenges.
Overlooking the importance of dissemination	Develop a plan for disseminating research findings. Outline how the results will be shared with the scientific community and the public.

Research Gaps and Future Directions

Despite the acknowledged role of funding in advancing biomedical research, significant research gaps persist. A primary gap is the need for comprehensive studies quantifying the direct economic impact of funding on research outcomes. This includes examining how financial investments translate into innovative solutions and improved health metrics. Additionally, there needs to be more empirical evidence addressing the challenges faced by under-represented groups and early-career researchers in securing funding **[**34]. This hinders efforts to promote diversity within the field. Furthermore, research on the relationship between team diversity and research productivity or innovation still needs to be completed. While transparency in funding mechanisms is crucial, systematic evaluations of existing practices and their effectiveness in fostering collaboration and ensuring equitable access to resources still need to be improved [35,36].

To address these gaps and enhance the future of biomedical research funding, several directions can be pursued (Figure 3).

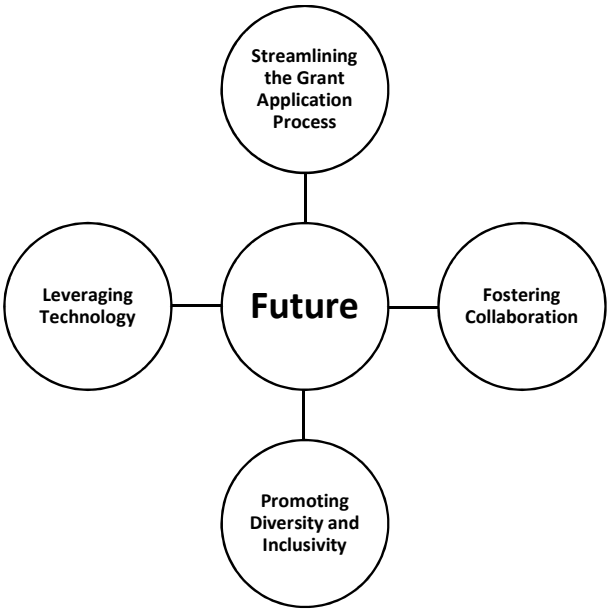


Figure 3. Future of Biomedical Research Funding

a) **Streamlining the Grant Application Process:** Funding agencies should streamline grant application processes to reduce administrative burdens and promote efficiency, ensuring that innovative projects receive the necessary resources.
b) **Fostering Collaboration:** Increased collaboration between government, private sector, and philanthropic organizations can create a more integrated funding ecosystem, enabling shared risk and investment in high-potential research areas.
c) **Promoting Diversity and Inclusivity:** Emphasizing diversity and inclusivity in grant awarding processes will foster a broad range of perspectives and solutions, driving innovation.
d) **Leveraging Technology:** Utilizing data analytics can facilitate informed decision-making in funding allocations and identify emerging trends and research needs.

Conclusion

This review highlights the pivotal role of strategic funding in driving biomedical research and innovation, particularly in addressing significant health challenges. The complexities of the funding landscape, marked by a convoluted grant application process and limited support for underrepresented groups, impede researchers' ability to secure necessary financial resources. While investments in biomedical research yield positive economic returns, comprehensive analyses linking funding to concrete health outcomes remain scarce. The need for enhanced transparency in funding mechanisms is critical to fostering creativity and efficiency in research efforts. Addressing these challenges will strengthen biomedical research and ensure a diverse array of perspectives is represented in the pursuit of effective health solutions.

Disclosure Statements

Conflicts of interest

The authors declare that they do not have conflict of interest.

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Authors' Contribution

RV- Conceptualization, data collection and analysis, literature search, manuscript writing, editing and final approval; AV- Literature search, manuscript writing, editing and final approval; MMS - Conceptualization, manuscript writing, editing and final approval.

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Use of AI tool: We have used Bard/Gemini Google and Grammarly to improve the English and readability of the article, but have rechecked the final manuscript and take full responsibility for its contents.

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