



Review Article

Enhancing primary healthcare delivery in Nigeria through the adoption of advanced technologies

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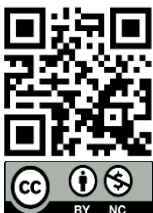
Abstract

Enhancing primary healthcare delivery in Nigeria by adopting advanced technologies holds substantial promise for improving healthcare accessibility, quality, and efficiency. Primary healthcare focuses on community-based, essential care that is practical, socially acceptable, and affordable. Despite efforts to improve healthcare delivery, challenges persist, particularly in rural and underserved areas. The aim of this study was to explore the transformative potential of technologies such as telemedicine, electronic health records (EHRs), health information systems (HIS), artificial intelligence (AI), and medical drones in addressing these challenges. Telemedicine facilitates access to healthcare in remote areas by overcoming geographical barriers. EHRs streamline administrative and clinical processes, enhancing patient care and safety. HIS improves data management, patient safety, and provider communication. AI revolutionizes diagnostics, treatment personalization, and operational efficiency. Medical drones offer innovative solutions for delivering medical supplies to remote locations. The paper also addresses the challenges associated with these technologies, including infrastructure limitations, regulatory issues, and data privacy concerns. Recommendations include investing in infrastructure, developing regulatory frameworks, building capacity, fostering public-private partnerships, engaging communities, and implementing robust data security measures. By addressing these recommendations, Nigeria can leverage advanced technologies to enhance healthcare delivery and achieve better health outcomes.

Keywords: Primary healthcare, telemedicine, health information system, artificial intelligence, medical drone

Introduction

As defined in the Alma Ata Declaration, primary healthcare (PHC) is "essential care based on practical, scientifically sound and socially acceptable methods and technology, made universally accessible to individuals and families in the community through their full participation, and at a cost that the community and country can afford to maintain at every stage of their development in the spirit of self-reliance and self-determination" [1]. The PHC system is a grassroots approach designed to address the community's leading health problems by providing preventive, curative,



and rehabilitative services [2,3]. The principles of PHC include essential healthcare, community participation, equity, inter-sectoral collaboration, and appropriate technology focused on the prevention, treatment, and rehabilitation of the community. These principles are the driving forces behind the efficiency of PHC and the hope of achieving universal health coverage (UHC). UHC ensures that everyone can access a comprehensive range of high-quality health services without financial hardship, from prevention to palliative care. Robust PHC is the most effective means to achieve UHC, with each country's path tailored to meet its population's needs and resources. Investing in PHC holistically addresses health needs, prepares for emergencies, and engages all sectors to promote well-being [4].

Rooted in the foundational principles of the Alma Ata Declaration, which positions primary healthcare as the cornerstone of healthcare systems, Nigeria's quest for UHC is evident in its proactive healthcare reforms. The declaration envisions primary healthcare as the initial point of contact for individuals, families, and communities, emphasizing proximity and accessibility to locally tailored healthcare services. Demonstrating a strong commitment to UHC objectives, the Nigerian Government established the National Primary Health Care Development Agency (NPHCDA) in 1992 through Decree 2, under the leadership of Prof. Ransome Kuti as the Minister of Health [5]. This initiative underscores PHC as the cornerstone of health systems, ensuring equitable access to care. The establishment of NPHCDA marked a significant step towards promoting health equity and universal access in Nigeria, guided by World Health Organization (WHO) benchmarks recommending coverage for at least 80% of the population [6]. PHC is designed to provide services based on people's needs, removing geographical, social, and financial barriers. Employing technologies in PHC that are suited to the community's needs is critical [7].

This paper explores how adopting advanced technologies such as telemedicine, medical drones, health information systems (HIS), and electronic health records (EHR), can revolutionize PHC delivery in Nigeria. By enhancing healthcare accessibility, quality, and efficiency, these technologies hold the potential to overcome existing barriers and improve overall health outcomes in the country. In addition, this review aims to identify the challenges and opportunities associated with integrating these technologies into Nigeria's healthcare system and to provide strategic recommendations for their effective implementation to enhance PHC delivery.

Nigeria's primary healthcare system

Nigeria operates under a federal system consisting of three tiers: federal, state, and local government. The federal government oversees tertiary and teaching hospitals, state governments manage hospitals, and local governments are responsible for PHCs [8]. PHC is a community-focused healthcare delivery approach introduced globally in 1978 [1]. Countries have made varying progress in implementing PHC. In Nigeria, recent revitalization efforts include initiatives like the Maternal Newborn and Child Health (MNCH) Week, PHC Reviews, the Midwives Service Scheme (MSS), and the National Health Management Information System (NHMIS) [9].

The WHO emphasizes the right to the best possible health, and each United Nations member should provide accessible, universal healthcare [10]. PHC is the most practical approach to fulfilling this obligation, as it addresses the unique needs of individuals, families, and communities. In Nigeria, PHC serves as the cornerstone of the healthcare system, representing the first point of contact for most citizens. It is designed to provide high-quality, affordable, and sustainable medical care, ensuring that healthcare is accessible to all, irrespective of social or economic status [5,11]. PHC not only forms the backbone of Nigeria's three-tiered healthcare system but also plays a vital role in fulfilling the national and international commitment to universal health coverage. Through its focus on accessibility and community-centered care, PHC is essential for meeting the health needs of the population at the most fundamental level.

Advanced technology adoption

The integration of advanced healthcare technologies plays a crucial role in enhancing the quality of healthcare services. These technologies empower clinicians to deliver more effective and personalized patient care, contributing to health equity. It increases patient safety, decreases medical errors, and strengthens the interaction between patients and healthcare providers. Technological advancements not only extend the capabilities of healthcare providers but also

expand patient access to care, particularly in remote and underserved areas, thereby improving overall health outcomes [12,13]. By integrating advanced technologies into PHC delivery, Nigeria can significantly improve the accessibility, quality, and efficiency of healthcare services, ultimately transforming the nation's health outcomes (**Figure 1**).

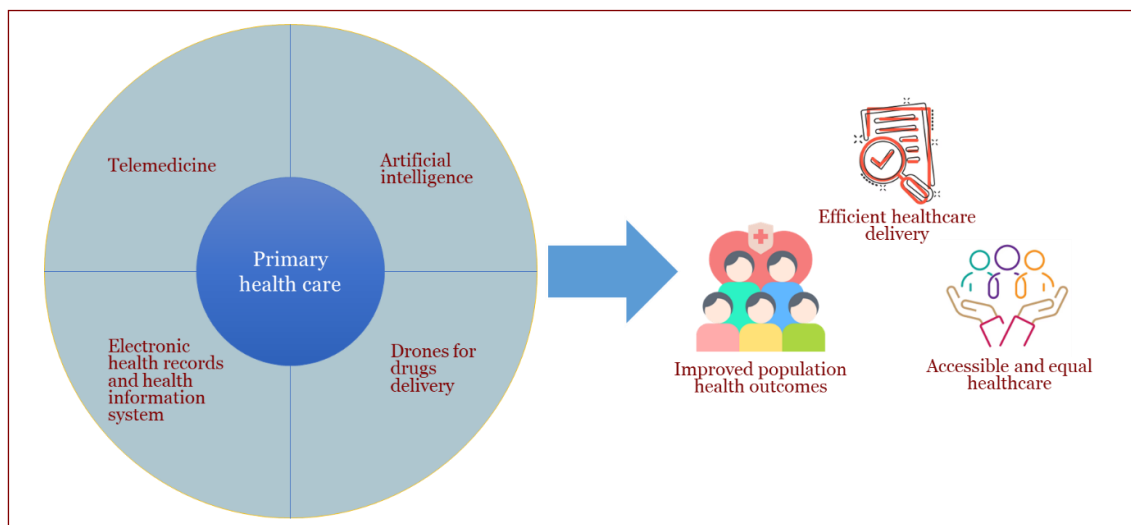


Figure 1. Summary of advanced technology integration in Nigerian primary healthcare and its benefits.

Telemedicine and mobile health (mHealth)

One of the most profound impacts of technology on primary healthcare in Nigeria is telemedicine. Telemedicine leverages telecommunications technology to provide clinical healthcare remotely. Telemedicine could be particularly beneficial in Nigeria, where there is a significant disparity in healthcare facilities and professional distribution between urban and rural areas. By leveraging digital technologies, telemedicine allows patients to access medical consultations and services from anywhere, reducing the need for physical travel to healthcare facilities [14]. This capability is crucial for individuals residing in rural regions, where traditional healthcare services are often limited or inaccessible [15].

Telemedicine's real-time video consultations and 24/7 availability enhance temporal accessibility, allowing patients to receive healthcare services conveniently. This flexibility reduces time and cost burdens associated with traveling to physical healthcare facilities, making healthcare more accessible to busy individuals and those with mobility limitations [16]. Telemedicine offers a cost-effective alternative to outpatient care, especially in rural areas where traditional healthcare services are scarce [17]. A systematic review suggests that telemedicine in diabetic retinopathy screening programs may be cost-effective, improving patients' workability, quality of life, and reducing travel expenses [18]. Mobile health applications are also utilized to monitor health conditions, provide health education, remind patients of medication schedules and appointments, and disseminate health information, reminders, and alerts through text messaging to reach a vast population, including those without smartphones [19, 20]. Additionally, telemedicine has been instrumental during health crises such as the COVID-19 pandemic, enabling continuity of care while minimizing the risk of virus transmission [21, 22].

Electronic health records (EHRs)

Implementing EHRs can significantly address the inefficiencies in Nigeria's primary healthcare system by enhancing service delivery, reducing administrative burdens, and improving patient outcomes [23]. This shift improves operational efficiencies by speeding up patient processing, reducing waiting times, and enabling healthcare providers to see more patients. A meta-analysis revealed that Clinical Decision Support Systems (CDSS) embedded in EHRs improved the proportion of patients receiving the desired process of care by an average of 5.8%, with notable variability across studies [24]. The integration supports informed treatment decisions aligned with current clinical guidelines, potentially improving patient outcomes.

EHRs also enhance medication management by automating prescribing processes and cross-referencing patient information to prevent adverse drug events. Standardized formats and accurate patient data further support clinical decision-making, enhancing patient safety and care outcomes [25]. Interdisciplinary collaboration is facilitated through EHRs, allowing real-time sharing of patient information across different healthcare settings [26]. Patient outcomes are significantly influenced by EHRs, particularly in terms of safety and engagement [27]. Continuous monitoring and follow-up care capabilities enable timely interventions, which are crucial for managing chronic conditions and preventing complications. EHR-integrated portals enhance patient engagement by enabling secure access to health information, supporting informed decision-making, and promoting adherence to treatment plans [28].

Health information systems (HIS)

While EHRs focus specifically on individual patient data and clinical workflows, HIS encompasses a wider range of functionalities. HIS comprises a range of technologies designed to collect, store, manage, and transmit health information, enhancing accessibility, service delivery, and patient outcomes [12]. Benefits of adopting HIS include the easy availability and accessibility of patient data, which is routinely collected and stored in the system [29]. HIS contributes to improved documentation quality and reduced errors, particularly medical errors. HIS simplifies access to health information, enhances documentation quality compared to paper-based methods, and reduces hospital costs. These systems also expand databases containing vast amounts of data, improving hospital management [30]. Cloud-based HIS platforms offer enhanced data security and flexibility, allowing healthcare providers to access, manage, and protect patient information from any location as well as from hackers, facilitating better patient care [31,32]. However, challenges such as data privacy concerns and the need for robust internet infrastructure must be addressed to maximize these benefits [31, 32].

Health analytics and artificial intelligence (AI)

AI is considered revolutionizing various sectors, particularly with the development of large language model (LLM) that enables computer systems to perform tasks requiring human-like intelligence [33]. AI-driven tools in medical imaging analyze X-rays, MRI scans, and CT scans with high precision to detect anomalies like tumors, fractures, and neurological disorders, often outperforming human accuracy [34,35]. By utilizing deep learning, these systems identify patterns indicative of early disease stages, such as cancer [34]. Additionally, AI excels in genetic data analysis by examining genetic markers and variations to predict the risk of genetic disorders [36]. In biometric data analysis, AI applications process data from wearable devices to monitor vital signs and detect deviations that may signal health issues [37]. In controlling infectious diseases, AI offers immense potential in Nigeria's public health systems. For instance, AI-driven diagnostic tools have been piloted in Lagos, where they improved early detection rates of tuberculosis compared to traditional methods [38].

In wearable technology, AI integration allows continuous collection of health data (e.g., heart rate, blood pressure, glucose levels, and sleep patterns) and provides real-time patient health insights [39,40]. Some studies have suggested the integration of AI monitoring to HIS could facilitate seamless tracking of patient health metrics [41]. AI-based wearable devices particularly offer benefits for patients with chronic conditions, by enhancing self-management, promoting self-sufficiency, and supporting adherence to treatment regimen [42].

Medical drones for drug delivery

Medical drones represent a groundbreaking innovation for addressing logistical challenges in delivering primary healthcare to remote and underserved areas of Nigeria. Poor infrastructure and lengthy transport times often hinder timely access to essential supplies. Drones provide a cost-effective and efficient solution by utilizing beyond visual line of sight (BVLOS) technology [43]. They are particularly valuable in emergencies, disaster response, mapping disease landscapes, and conducting search and rescue operations in rugged terrains [44,45]. Logistics firms like Zipline have introduced innovative drone delivery models, reaching over 13 million Nigerians across Kaduna, Cross River, and Bayelsa States and serving more than 1,005 healthcare facilities since August 2022 [46]. These services have significantly improved healthcare delivery

by ensuring timely access to medications, vaccines, and blood products, reducing maternal and child mortality rates, and supporting critical rural clinics [47].

Despite their advantages, drones are limited by payload capacity (typically 2 to 4 kg) and face challenges such as safety, security, and privacy concerns [48]. Additionally, their use may displace jobs in traditional transportation sectors. Addressing these issues requires proactive measures like reskilling programs, creating new opportunities in drone operations, and establishing robust regulatory frameworks [49]. International initiatives, such as the "Medicines from the Sky" project in Telangana and the I Drone initiative in Northeast India, highlight the potential of drones to enhance healthcare access in challenging terrains [50]. The summaries on the advanced technology utilization in primary healthcare delivery are presented in **Table 1**. The use of telemedicine is also constrained by language barriers as Nigeria is one of the most linguistically diverse countries in the world, with over 500 distinct languages spoken across its regions.

Table 1. Summaries of the advanced technology integration in primary healthcare delivery based on studies in Nigeria and other relevant countries

Study population	Type of technology	Benefits of technology integration	Reference
Individuals with or at risk of MDR-TB in Nigeria	Telemedicine, including vDOT, remote consultations, and digital health monitoring	Improved access to care, enhanced treatment adherence, cost reduction, minimized transmission risk, real-time monitoring, and increased patient engagement	[14]
Multi-stakeholders in Nigeria	eHealth, telemedicine, mHealth, and EHR	Strengthened health systems, improved governance and coordination, cost-effective service delivery, enhanced capacity building, and support for achieving UHC	[23]
Pregnant and children in Nigeria	MedStrat health insurance management system	Increased health insurance enrollment, improved access to maternal and child health services, enhanced efficiency in health insurance management, and reduced maternal mortality rates	[51]
Federally funded tertiary health institutions in Nigeria	Telemedicine, EHR and digital health platforms	Improved healthcare continuity, cost-effectiveness, enhanced health equity, better emergency preparedness, and the ability to address healthcare workforce shortages	[27]
Pregnant mothers and their spouses in Nigeria.	Text message-based telemedicine (Text4Life)	Improved emergency transportation, increased use of healthcare facilities, reduced maternal mortality, and better communication between patients and healthcare providers	[52]
Diabetes mellitus patients in Nigeria	mHealth with voice calls, text-messaging, and basic digital features for diabetes management	Increased access to healthcare, improved treatment adherence, cost reduction, enhanced health education, and better management of diabetes-related outcomes	[19]
Patients and healthcare personnel in Nigeria	Blockchain-based Electronic Health Data System (BEHeDaS)	Enhanced data security, interoperability, transparency, scalability, patient trust, and compliance with HIPAA standards for medical records management	[53]
Healthcare workers in Nigeria	AI-based diagnostic tools and automated systems	Improved diagnostic confidence, reduced medical errors, minimized time spent on monotonous tasks, and enhanced efficiency in healthcare delivery	[54]
Infants and rural communities in Nigeria	Medical drones for vaccine delivery	Improved vaccine distribution, reduced transportation challenges, enhanced healthcare equity, and decreased infant mortality	[55]
Patients in rural areas of Rwanda	Medical drones for delivering blood products	Faster delivery times, reduced blood wastage, improved emergency responses and reduced transportation challenges.	[45]

Study population	Type of technology	Benefits of technology integration	Reference
Multi-stakeholders in Ethiopia	mHealth, EHR, AI, and cloud-based applications	Improved access to healthcare, enhanced clinical decision-making, increased patient engagement, and cost-effectiveness	[56]
Diabetes mellitus patients in Ethiopia.	Wearable health devices for diabetes management	Improved health self-management, reduced hospital visits, enhanced real-time feedback, and better glycemic control	[57]
Healthcare providers and patients in Sub-Saharan African countries	Mobile-based diagnostics, AI-driven predictive analytics, and telemedicine platforms	Improved diagnostics, personalized medicine, streamlined healthcare operations, enhanced public health surveillance, and better disease prediction and management	[58]
Patients and clinicians across African countries.	Smartphone apps, text messaging services, home-based monitoring devices, wearables, and telemedicine platforms	Improved self-monitoring, remote interactions, telemedicine, education, and research facilitation	[20]

AI: artificial intelligence; EHR: electronic health records; MDR-TB: multidrug-resistant tuberculosis; UHC: universal health coverage; vDOT: video-based directly observed therapy.

Challenges

The adoption of advanced technologies in Nigeria's PHC faces numerous challenges. Limited access to rural and underserved areas, poor internet connectivity, and a lack of digital devices hinder the utility of technologies requiring long-distance monitoring [59]. Marginalized populations, including those with disabilities or limited education, face additional barriers to access [60]. Regulatory complexities, such as overlapping mandates between the National Agency for Food and Drug Administration and Control (NAFDAC) and the Standards Organization of Nigeria (SON), further complicate implementation [61]. In terms of HIS implementation, issues such as inadequate broadband infrastructure, insufficient budgets, a lack of skilled IT personnel, and frequent power outages impede progress [29]. A previously published review highlighted that the success and failure of HIS adoption among developing countries heavily rely on human resource quality, organizational management and strong leadership, and financial factors [62]. Additionally, data security concerns, poor integration, and dependency on donor funding lead to unsustainable systems and underutilization [30,31].

Telemedicine, an essential component of modern healthcare, also faces significant challenges in Nigeria. The country's linguistic diversity, with over 500 spoken languages, increases implementation costs for multilingual platforms, translation services, and localized materials [63]. Findings from a systematic review suggest that the telemedicine implementation in African countries is limited by the language barriers [64]. Health and digital literacy challenges, especially among rural and socioeconomically disadvantaged populations, further limit telemedicine adoption. This is already a concern in the United States, particularly among Spanish-speaking communities [65]. Incorporating AI into Nigeria's healthcare system raises significant legal and ethical concerns. Key issues include regulating AI algorithms, ensuring accountability for AI-driven decisions, addressing algorithmic bias, and protecting data privacy. Existing frameworks, such as the National Health Act (NHA) and Nigerian Data Protection Act (NDPA), provide a foundation but require strengthening to address these challenges [58, 66]. Integrating drones into healthcare delivery offers potential solutions to logistical challenges in remote areas where poor infrastructure limits traditional logistics. Drones can efficiently transport medical supplies; however, limitations such as payload capacity, safety and security concerns, and high operational costs hinder their widespread use [48]. High costs associated with acquiring, maintaining, and operating drones may strain Nigeria's already limited healthcare budget, especially given the reliance on donor funding for many healthcare projects [67]. Furthermore, the shift to drone delivery could also impact jobs related to traditional transportation methods [68].

Recommendation and future directions

Integrating advanced technologies into Nigeria's PHC system requires a strategic and coordinated approach to address key challenges, where the summaries of the challenges and solutions are presented in **Figure 2**. Expanding broadband and internet infrastructure is critical for supporting telemedicine and HIS, particularly in rural and underserved areas where internet access is minimal and urban centers face frequent interruptions. Collaboration between the government, private providers, and international donors can accelerate infrastructure development. Streamlining licensure processes for telemedicine providers across state lines and clarifying the roles of regulatory bodies, such as NAFDAC and SON, are essential to reduce regulatory complexities. Updating the NDPR with enhanced data security provisions can safeguard patient information in telemedicine and electronic health systems. Efforts to improve accessibility should include multilingual platforms, assistive devices for individuals with disabilities, and educational initiatives targeting marginalized populations.





	Challenges	Solutions
Telemedicine 	<ul style="list-style-type: none"> Limited internet access. Licensure issues Language barriers Digital literacy gaps 	<ul style="list-style-type: none"> Broadband infrastructure. Streamline state licensing. Develop multilingual telemedicine platforms. Conduct health and digital literacy campaigns.
HIS 	<ul style="list-style-type: none"> Inadequate ICT resources. Budget constraints. Power outages. Low ICT skills among medical staff. 	<ul style="list-style-type: none"> Investments in infrastructure. Training programs for healthcare personnel. Renewable energy solutions. Leadership and management capacity building.
AI 	<ul style="list-style-type: none"> Algorithm bias. Lack of accountability frameworks. Public distrust and low awareness. 	<ul style="list-style-type: none"> Establish comprehensive regulatory frameworks. Update the regulations for AI-specific issues. AI education and awareness program.
Drones 	<ul style="list-style-type: none"> High costs and reliance on donor funding. Limited payload capacity. Shortage of skilled personnel. 	<ul style="list-style-type: none"> Public-private partnerships to share costs. Upskilling programs for drone operation and maintenance. Focus on lightweight and time-critical supplies.

Figure 2. Challenges in adopting advanced technologies in the Nigerian healthcare system and their proposed solutions.

For HIS, cost-effective solutions should focus on upgrading existing ICT resources, providing renewable energy for consistent power supply, and equipping healthcare personnel with the skills needed to address ICT gaps. Equally important is strengthening leadership and management capacities within healthcare facilities to ensure effective implementation and long-term sustainability. Investments in user-friendly systems can enhance adoption rates, while incremental funding strategies beyond donor dependency can help balance immediate needs with

sustainable growth. Similarly, AI holds transformative potential for Nigeria's healthcare system but requires robust legal and ethical safeguards to be effectively implemented. Regulatory frameworks must ensure transparency, accountability, and safety, addressing challenges like algorithmic bias and data misuse. Collaborative efforts involving developers, legal experts, and healthcare providers are crucial to guide ethical AI adoption. Updating existing laws, such as the NHA and NDPR, to include intellectual property rights and measures to mitigate algorithmic bias will strengthen governance. Finally, public awareness campaigns and AI education for healthcare workers can build trust and ensure these technologies are effectively utilized.

Drones present an opportunity to enhance healthcare delivery in remote areas by addressing logistical challenges. However, their high costs, limited payload capacity, and operational risks must be considered. Drones should focus on delivering lightweight and time-critical medical supplies, such as vaccines and blood, while heavier items remain within traditional logistics systems. Establishing safety protocols and monitoring systems is crucial, especially in conflict-prone or densely populated regions. Public-private partnerships can offset financial burdens, while local manufacturing and maintenance could reduce costs and create jobs. Targeted training programs to develop technical skills are necessary to address the current shortage of qualified personnel for drone operations. Complementing drone adoption with upskilling initiatives and alternative employment opportunities can help mitigate the potential impact on traditional transportation jobs.

Conclusion

Integrating advanced technologies like telemedicine, EHRs, HIS, AI, and medical drones into Nigeria's PHC system has the potential to significantly improve healthcare delivery, access, and outcomes, particularly in underserved regions. However, this integration faces potential threats, including data security risks, such as breaches and unauthorized access to patient information, as well as ethical concerns like algorithmic bias in AI systems that may lead to inequitable healthcare outcomes. Limited digital infrastructure and frequent power outages could impede effective implementation, while high costs of acquiring and maintaining technologies may strain the healthcare budget. Additionally, the displacement of jobs in traditional logistics and the risk of over-reliance on donor funding pose socioeconomic threats. Strengthening policies and regulations is essential to ensure secure and standardized technology use, while investments in infrastructure, training programs, and local capacity building can address these challenges. Promoting digital literacy and creating culturally sensitive solutions will help bridge gaps for vulnerable populations. Collaboration between public and private sectors is crucial to drive innovation, improve technology integration, and refine strategies through ongoing evaluation.

Ethics approval

Not required.

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None to declare.

Competing interests

All the authors declare that there are no conflicts of interest.

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Underlying data

Derived data supporting the findings of this study are available from the corresponding author on request.

Declaration of artificial intelligence use

This study used artificial intelligence (AI) tools and methodologies in the following capacity for manuscript writing support: AI-based language models, such as ChatGPT was employed to language refinement (improving grammar, sentence structure, and readability of the manuscript). We confirm that all AI-assisted processes were critically reviewed by the authors to ensure the integrity and reliability of the results. The final decisions and interpretations presented in this article were solely made by the authors.

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